तमसो मा ज्योतिर्गमय

SANTINIKETAN
VISWA BHARATI
LIBRARY

D.
372·35
R 816

THE UNITY OF LIFE

THE UNITY OF LIFE

A BOOK OF NATURE STUDY FOR PARENTS AND TEACHERS

BY

H. R. ROYSTON M.A.

WITH SIXTEEN PLATES AND TWENTY-THREE
DIAGRAMS IN THE TEXT

GEORGE G. HARRAP & COMPANY LTD.
LONDON CALCUTTA SYDNEY

First published 1922
by George G. Harrap & Co. Ltd.
39–41 *Parker Street, Kingsway, London, W.C.*2

Printed in Great Britain by Neill & Co. Ltd., Edinburgh

PREFACE

THIS book has been written with the primary object of assisting parents and all others who are actively interested in the work of teaching, whether they wish to impart a systematic knowledge of nature study, or whether they desire merely some help in answering the eternal questions " How ? " and " Why ? " put by their youthful charges. To those who are responsible for the training of teachers it has become clear that the importance of evolutionary biology as a basic subject in the course of training cannot be exaggerated. Lecturers on the principles of teaching and hygiene have been asked by the Training College Association to consider means for giving greater weight to the biological side of their subject. In this connexion the present volume should offer suggestions for the more adequate treatment of a subject the importance of which is now admitted to be beyond dispute.

It is hoped that the book may also prove of some service to sections of the general public. Those who are keenly interested in the problems of evolutionary biology often fail to assimilate all that they read because they lack knowledge of elementary morphology and physiology. On the other hand, there are those who, though they possess some acquaintance with what is generally known as elementary biology, have never considered general principles such as the essential unity of life and the truths of evolution and inheritance.

The book has a further aim—to help all who are brought into close association with children to impart naturally and easily a knowledge of the main facts of the reproduction of life. Too often awkward questions have been evaded and a difficult subject merely neglected. Here a sane and healthy mode of approach is suggested that will remove this temptation; but it must be observed that no attempt has been made to offer more than an outline of the manner in which such information may be given.

It is not claimed that any new facts will be found in the book. There is, however, something new in the purposes to which these facts are put and in their mode of presentation. The author has made extensive use of the work of others, and is accordingly under an obligation which he would wish to acknowledge. He believes, however, that the principal facts are the common property of all biologists. He desires particularly to express his gratitude to Mr D. Ward Cutler, of the Rothamsted Experimental Station and Joint Editor of the *Journal of Applied Biology*, and to Mr S. Clegg, Headmaster of Long Eaton County Secondary School, who read the manuscript and made valuable suggestions regarding subject-matter and text respectively.

H. R. R.

CONTENTS

CHAPTER PAGE

INTRODUCTION 11

I. LIFE 23

II. SIMPLE FORMS OF LIFE 31

III. A TYPICAL PLANT 47

IV. A TYPICAL ANIMAL 77

V. SEEDS AND EGGS 99

VI. MARRIAGE AMONG PLANTS 111

VII. MARRIAGE AMONG ANIMALS 130

VIII. SOME DIFFERENT KINDS OF FLOWERING PLANTS 139

IX. SOME DIFFERENT KINDS OF ANIMALS 157

X. THE ORIGIN OF LIFE 189

XI. METAMORPHOSIS AND ALTERNATION 197

XII. SPONGING—AND CO-OPERATION 210

XIII. CARNIVOROUS PLANTS 223

XIV. COLOUR IN ANIMALS AND PLANTS 231

XV. DARWINISM 246

XVI. SOME PRIMITIVE ANIMALS AND PLANTS 258

INDEX 275

ILLUSTRATIONS

PLATES

PLATE PAGE
I. A Wood in Winter *Frontispiece*
II. Nest and Eggs of the Yellow-hammer (*Emberiza citrinella*) 28
III. Hawthorn (*Cratægus oxyacantha*) 50
IV. Horse-chestnut (*Æsculus hippocastanum*) 72
V. A Spring Scene: Wild Hyacinths (*Hyacinthus nonscriptus*) and Young Bracken (*Pteridium aquilinum*) 112
VI. The Flowers of a Male Willow-tree 124
VII. The Flowers of a Female Willow-tree 126
VIII. Midsummer: a Water-lily Pool 146
IX. White Water-lilies (*Nymphæa alba*) 148
X. *Nemo me impune lacessit!* 154
XI. A Swan (*Cygnus olor*) 158
XII. A Toad (*Bufo vulgaris*) 198
XIII. A Beech-wood (*Fagus sylvatica*) 214
XIV. Caterpillars of the Puss Moth (*Dicranura vinula*) 240
XV. A Hen Partridge (*Perdix cinereus*) 244
XVI. Marsh Horsetail (*Equisetum palustre*), showing Nutritive and Fruiting Shoots 264

ILLUSTRATIONS IN THE TEXT

FIG.
1. A Unicellular Plant such as Protococcus 32
2. An Animal or Vegetable Cell dividing 37
3. Amœba 40
4. Paramœcium 44
5. A Wallflower Plant 48
6. A Plant Stem in Longitudinal and Transverse Section, showing Vascular Bundles 54

FIG. PAGE

7. An Experiment to demonstrate the Transpiration of Water by a growing Plant 55
8. An Experiment to demonstrate the Action of Root-pressure 62
9. Experiments to demonstrate the Effects of growing Plants in Air deprived of Carbon Dioxide 68
10. An Experiment to show Plants returning Oxygen to the Air 71
11. An Experiment to demonstrate that growing Plants breathe in Oxygen 75
12. The Digestive System of a Mammal 82
13. The Circulatory System of a Mammal 89
14. A Diagrammatic Representation of the Upper and Lower Bones of a Limb 94
15. A Bird's Egg 107
16. Inflorescence of a Wallflower 114
17. A Feather 160
18. The Radula of a Snail 174
19. The Body of an Earthworm, showing the Setæ 178
20. Breathing-tubes of an Insect 179
21. Cnidoblast of Hydra 186
22. The Life-history of the Malarial Parasite 216
23. Fern Prothalli 261

INTRODUCTION

IN an ideal world the teacher of the child would be its parent. But our modern system is a very complex one, resulting in specialization on every hand. The father, owing to his employment in some specialized occupation, has no time at his disposal in which to educate his children himself ; in consequence of his expert knowledge of his own subject and his almost inevitable ignorance of any other, he is quite unfit as a rule to do so, and incapable even of influencing their education. But he can from his earnings, either through rates and taxes, or through them and by direct payment, pay some one else to concentrate all his energies on the art of teaching, as he—the parent—has concentrated his on some other art, and so give his children an education that is far in advance of that which he would be able to give them by his own unspecialized and untrained efforts. Education is no longer regarded merely as the art of imparting knowledge, or even of ensuring that it is assimilated, and there are still those who are of opinion that Gertrude's method would result in the development of men and women better fitted to face life and to serve their fellows than are those resulting from a national system of education. Still, it is not likely that any will to-day maintain that an education imparted amid the restrictions of the home would produce results likely to fit children for modern, progressive life, with its competition and its complicated activities on the one hand and its still primitive disregard for the weak, slow, and incompetent on the other. Yet the necessity for ' moral education ' is perhaps more strongly recognized to-day than it ever has been, and those who are most bitterly opposed to so-called ' sectarian ' teaching in schools are generally agreed as to the necessity for moral, if not religious, instruction.

It is, however, this teaching that should be, and could much better be, given in the home, not with a view to divorcing religion from the teaching in school, but to developing and amplifying it. Parents have shown a willingness to instruct their children in the mysteries of religious faith themselves, and, so far as a large section of the community is concerned, though not, it is believed, of a majority, a willingness to eliminate all religious teaching from the schools and to impart it within the family circle. In view of this it is astonishing that a vast majority are unwilling to go a step farther and to accept responsibility for imparting within the family circle a knowledge of the facts of life so far as it is essential to the developing child. There has arisen a large and rapidly growing body of parents who have indicated that they are desirous that their children should have these facts explained to them by their teachers.

If there is one thing it might be confidently expected the average parent would claim as his unalienable right, surely it is the right to explain to his own offspring something about their physical selves. Parents who have evaded this duty, and surely it is a duty, are liable to be regarded as guilty of moral cowardice to a degree that calls for some censure. There seem to be but two grounds upon which such negligence as undoubtedly exists may be condoned : one is that those whose business it is to teach, and to teach others how to teach, have failed to show the parent how the vitally necessary information should be given ; the other is that a number of public-spirited professional teachers have come forward and have undertaken in certain circumstances to provide instruction in these matters to children whose parents are willing they should be so instructed. It is because parents as a whole have neglected a duty, unworthily delegating it to others, that the effort to produce these pages has been made. It is hoped that they may be effective in showing parents themselves how the necessary facts may be imparted. The effort, however, has been made primarily on behalf of those teachers in elementary and secondary schools who have responded to the growing demand for instruction.

The only natural way in which to place the facts of life before children is in the teaching of nature study, which has already become established in school curricula. In view of the large place nature study occupies in the education of the teacher, it is regrettable that the subject is allowed so small a part in school time-tables. Arithmetic in an elementary school is accorded some five hours weekly; together with wider mathematical studies a longer period is given it in secondary schools. English, properly accorded an important place in all curricula, is provided with no less time, and directly and indirectly English subjects generally occupy an even larger place in the time-table. The study of life, which might be expected to demand the first attention of living, conscious beings, gets just such time as can be spared from ‘ more important ’ subjects.

This is probably due to the fact that nature study has in the past had one aim only, the training of observation. The importance of accurate observation cannot be overrated, but its value becomes more apparent after school life. As its results have not been reflected in examination marks—at least, so it is thought—it has never become popular. However, notwithstanding the value of training in observation for post-school life, it must be admitted that a mere capacity to observe is of little value unless it is accompanied by a knowledge of how to utilize the facts observed. It is not useful to know that a cow gets up on its hind-legs first and a horse on its forelegs, or that a caterpillar has six true legs and a number of 'prolegs,' unless what lies behind those facts is known and understood. The teaching of nature is doomed to failure if it is to consist of nothing but training the powers of observation. Children observe these things more accurately than we of a more mature age do, and have a supreme contempt for the efforts made to elicit commonplace facts of this description as though a correct answer implied the possession of some special intelligence. The child is above everything an investigator : his chief occupation is the observation of his environment. Those who observe children most closely will probably agree that to them the world is a miracle which they are constantly trying to solve. Their attitude toward matters of ordinary observation may be illustrated by the following anecdote, for the truth of which the writer can vouch. The teacher of the first standard of a public elementary school had drawn from her children the information that a cat is smaller than a dog and that it has four legs. She then asked whether a cat has feathers, scales, or fur on its back, and was rewarded by "Lor blimey, miss ! Ain't you never seen a cat ?" from a boy in the front row.

Had the greater mysteries of life never been wrapped in secrecy there would have been no need to dwell upon the subject in the introduction to what is intended to be in many respects a very ordinary book on the teaching of nature study, and it is necessary at this stage to offer a word of warning. Heretofore such instruction regarding life as has been given has been well balanced—that is to say that, in teaching animal life, the different aspects dealt with have been given equal attention, no undue stress having been placed upon life-history, or food, or locomotion, or coloration, or respiration ; only reproduction has been avoided, as though it were something quite different from other manifestations of life, something not quite natural and therefore to be avoided. In the teaching of botany balance has also been maintained, though, since the inclusion of botany in the curricula of girls' schools was intended to serve as an introduction to the study of the reproduction of life, fertilization and the development of the seed were specially stressed ; but these failed in their object, so far as their object was to teach the girl something about herself, and they failed because no attempt was made, or, if made, was not made sufficiently clearly, to link up plants and animals ; their differences were pointed out, but they were relegated to two watertight kingdoms that do not, in fact, exist. The warning referred to is that, when a scheme of nature study aiming at teaching all the facts of life is drawn up, care must be exercised not unduly to emphasize the facts of reproduction. The aim of the subsequent chapters is to show how these may be introduced step by step, until they become apparent as they occur naturally in the economy of nature. We must teach the child to apply his knowledge and to reason about the facts. And this brings us back to the point at which it was observed that a mere acquaintance with facts is not knowledge. Girls have for years been taught the functions of pollen and the ovule, but have seldom been helped toward an appreciation of what the application of those facts to animal life might mean. We have succeeded in teaching them to gape, but have failed to teach them to perceive. We must demolish that imaginary wall we have erected between plants and animals.

In the past the objects aimed at in teaching nature study have been somewhat circumscribed, though the individual teacher has been more or less successful in accordance with the breadth or narrowness of his aims. When the practice of observation alone is aimed at, the subject is abundantly entitled to a place in the school curriculum. How much more, then, is its inclusion justified if it can be shown that much more than this can be attained by the instructed and sympathetic teacher ? The value of the power of observation cannot be placed too high. He who sees most lives a fuller life in every respect ; phenomena that pass unnoticed by the man who has never been taught to observe impinge on the consciousness of him who has. The boy who knows what colours are found on the wing of a butterfly and how its organs are arranged will continue to observe long after he is withdrawn from the country or the class-room in which he was taught. He will derive more pleasure from a picture gallery, because he will see more in each picture ; if his study of nature has been well balanced he will hear more in a sonata of Beethoven, even though he may know nothing of ‘ the appreciation of music.’ He will impress his employer by his alertness and will earn the reputation of being a ‘ live man.’ In business it is a great asset to be able to ‘ notice ’ things. It is not alleged that the power to perceive cannot be acquired otherwise than through nature study, but it is certain that no more suitable method is available.

To-day we can justly congratulate ourselves that we are in advance of an age—not so very far distant, however—that failed to recognize its duty to the animals upon which it was dependent. We no longer permit cattle destined for slaughter to be fastened to a ring in the ground and ‘ baited ’ by muscular brutes with sticks until they are in a state of madness and exhaustion, with a view to making the flesh tender. Neither does the village turn out in a body and stone wrens on St Stephen’s Day. We even impose small fines upon those who work sick horses or who drive lame sheep, provided the offence is so outrageous as to offend the sight. We may congratulate ourselves that in these days such occurrences offend the sight and feelings of most people. Yet one has only to cross the Channel to see the most hideous torture perpetrated upon animals destined for human food—fowls brought to market tied into bundles by the legs, thrown down in the sun and slowly dying of thirst before the eyes of prospective buyers. In Italy things are even worse. There the love of killing has eliminated a vast amount of bird life from the country. The Italians have eaten all their singing birds, and take advantage of their migratory instincts to take toll of ours. Any remonstrance is met with " But why not ? They are not Christians." Nature study cannot fail to implant a regard for the feelings of other animals. The subject, when adequately taught, must instil in the student a tremendous reverence for all live things, and it is well known that, notwithstanding the necessary dissection that must take place if botany is to be taught on reasonable lines, children who have learned something of the marvels of plant life will not willingly destroy flowers uselessly. The sad sight of masses of flowers plucked for the sake of plucking and then thrown away will no longer offend the eye of the nature lover when nature study is taught from the lowest standard of the elementary school to the highest form of the secondary.

But the ultimate aim of the teaching of this subject should be, and it is hoped to show can be, the removal of the danger—indeed, the certainty—of children reaching an advanced state of adolescence knowing nothing of their origin or, worse, having a degraded and hideous conception of it. This point need not be emphasized here. There is a considerable amount of printed matter on the subject of sex instruction, and a grave need, owing to the default of the parents, of instruction in school on its mysteries. The need is on all hands admitted, and it is for the biologist to show how it may be introduced. The parent has allowed one of his privileges to fall to another. It is a practical question that has been talked nearly to death. Public bodies have discussed the subject and reported upon it ; all are agreed upon the necessity of full instruction ; they have even decided that it must be given. But there it ends. So far it has not been given. Half-hearted attempts have been made, but there is no guidance, and no initiative to back the decision.

It is not proposed to deal here with the economic value of the teaching of biological science, because this is a book for teachers. The specialist teacher will appreciate that it is not every child who will develop into a biologist or who may find in biology his life's work. But so much has been done and to such an extent has mankind benefited by the work of the biologist that it is to be hoped that by the right teaching of nature study in school, by its taking a large place in the time-table, some may develop an enthusiasm for the subject and may adopt it as a profession. It is an essential part of the preliminary training of the medical man, but the numbers of others who adopt it as their life's work are small indeed. Yet some of the greatest discoveries have been made by men and women who were biologists and not medical practitioners, or by medical men who were not practising as such, but were devoting their lives to zoological or botanical research. Is it too much to say that the fact that there is still enough wheat in the world to feed an increasing population is due to such, or that, except for these, white men could not live as they do in parts of the world that were thought to be uninhabitable for Europeans ? In view of the meagre teaching of the subject that has so far been given in school, compared with, for instance, the teaching of physical science, we may confidently hope that when the subject attains its proper place in the curriculum of all schools we may look forward to the development of research along lines previously undreamed of. Since Malthus' day the study of economics has been alternately under the guidance of those who do and those who do not fear that the growth of population may press upon production, and that the end of this world will or will not be starvation. At present the pessimists seem to hold the field. The surest hope for the world's food-supply lies in the dissemination of knowledge of biological science, so that those who can acquire sufficient interest in it may at an early age shape their course toward a life of biological research.

The reader who looks herein for courses in biology graded for the different forms of a school will be disappointed. Such work would provide material for a volume in itself. So much will depend upon the average duration of school life, the time that an overcrowded curriculum can allow, and the importance of subjects that are to be sacrificed to it. The opportunities offered by the compulsory lengthening of school life should be grasped to the full.

Neither will teachers find chapters devoted to method, which will vary with the genius and knowledge of the individual teacher and the opportunities he has of handling specimens and practising field work; and these will differ in rural and urban districts. Failure will in most cases result when the teaching is not based upon reverence for the objects studied. The writer has before him reports upon a camp school held during the early summer. The following extracts taken from accounts of the work done in nature study, written by students in training for the teaching profession, tell their own sad tale and indicate a method that is fundamentally wrong:

> . . . The children returned to camp with the collections they had made during the ramble. One had picked thirty-seven different species of flower. . . .
>
> . . . The result of the afternoon was extremely satisfactory. Most of the class had gathered huge bunches of flowers. . . .

No word of reproof! No regrets! The students did not remark in their reports whether the thirty-seven kinds or the huge bunches contained any of the rarer flowers, many of which are on the verge of extinction. Similarly there has come to the writer's notice a method of teaching observation and, presumably, of preparing boys for the nature-study badge issued to boy scouts. The scouts were taken out into the country and shown a caterpillar of a privet hawk moth feeding on a privet hedge. The officer in charge pointed out the wonderful protective coloration scheme of the animal—the light side of the leaves exactly matching the green of the larva, and the purple stripes representing the shadows cast by the narrow, pointed leaves. He drew careful attention to the difficulty in detecting the larvæ in the foliage of privet and ash, and explained that this was a device of nature to save a large and vulnerable creature from extermination, and then added, " Now, off you go, and see who can collect the most before five o'clock." The privet hawk is as harmless an animal as exists, and on account of its large size and the small number of its eggs it can never, so far as this country is concerned, attain numbers that would make it an obnoxious insect or bring its existence to the notice of ordinary, unobservant people. What was to become of the caterpillars when they had been collected and produced as evidence we do not know, but we feel some lack of confidence that the boys would finish their excursion with any particular regard for the beauty of one of the handsomest caterpillars to be found in England. The writer has some reason to believe that the incident recorded is not now characteristic of the methods adopted in the study of nature by boy scouts. The amount of destruction—that is, dissection either of plants or animals—involved in nature study should be reduced to a minimum. It is absolutely essential that each child shall handle, and in many cases dissect, the specimen, but the reason for the dissection should be carefully explained. It should be emphasized at the outset that life, so easily taken and impossible of replacement, may be sacrificed only for an adequate reason. The results of such teaching will be obvious. A reverence for live things—plants and animals—once inculcated (and it must be inculcated, for it seems to be true that we are born with a love of killing in our nature) will develop into kindliness to animals, a love for living things, an appreciation of beauty that is indeed more than skin deep, and a more charitable and tolerant attitude toward our fellows.

The chief object in nature study is the study of life. We do not really know what life is ; we are only conscious of its manifestations. Endeavours will be made to show how children may apprehend the fact that a plant is as truly alive as, say, a cat. We need to impart knowledge and to teach the child ; one result of teaching should be learning, and learning must include the reception of facts that will lead to the acquisition of other facts which the child can only gain by his own efforts. We are in danger of forgetting in our discussions on the different methods of teaching that it is the children who are of first consideration. Here and there will be found indications of method —the introduction of experiments, and so forth—but the teacher who studies method too closely is unlikely, we now know, to attain individuality in teaching, for although it is true that a naturally good teacher will become a better by the study of method, and that it is essential to a naturally poor teacher, each of us possesses individual powers, and it is the teacher's duty to himself and those he teaches to avoid all occasion of cramping those powers. In no case is this more true than in the teaching of biology. It is probable that the subject will become more and more the property of the specialist, but it will be long before the specialist teacher of nature study appears in the elementary school, in the most junior standards of which the preliminary instruction must be given. It will be obvious that a great deal that appears herein cannot be assimilated by children at the beginning of their school life; but if the teacher ensures that he himself is fully informed, he will be able to devise such lessons as are suitable to the age of his class and to the time at his disposal.

THE UNITY OF LIFE

CHAPTER I

LIFE

WE do not really know anything about life. We cannot see it, we cannot create it. We can always destroy it, but we have not yet succeeded in replacing or rekindling it even when it has but recently been extinguished in its little house—the shell or shrine in which it was manifested. So we realize that it is not life we see, but merely its manifestations. Life is, therefore, a great mystery, and may remain so to the end of time.

Life exists and is manifested in both plants and animals. The child may not appreciate its existence in plants positively, but most children grasp it negatively. If asked " What things are alive ? " he will answer " Animals," or, perhaps, " A cat," or " A dog." If asked then if plants are alive he may, and probably will, say " No." Yet children examining plants growing in a garden may frequently be heard to say to others who are engaged in roughly handling the plants, " Don't. You'll kill them." Are, then, plants alive, in the same way that animals are ? It depends upon what is our definition of life. No dictionary definition will help us, and in teaching children about it no didactic method will avail. Since we are going to study the question throughout this work directly from nature, we will take any animal that by common acceptance is admitted to be alive. We might take one of ourselves, but man's place in the animal kingdom is a subject that, while it must be placed before children in the study of nature, can more suitably be introduced at a later stage, when he can be slipped into his place naturally and without the creation of any surprise or difficulty in the mind of the pupil. We will assume, then, that a dog is the most easily available animal in which to study the manifestations of life, and if the dog be a puppy so much the better will it serve our purpose.

The dog, or the puppy, breathes, eats, grows, moves. These manifestations will be apparent to the youngest child, and the information may be drawn from him. Experience shows that the existence before the class of the living object tends to destroy reserve, and that children excitedly volunteer information, which must, however, be suitably guided toward the points it is desired to bring out in the lesson. Are these manifestations exhibited by a plant? Any growing plant may be introduced at this stage, and it is of some importance that the plant be actually alive, and not uprooted and in a state of suspended animation, as an uprooted plant would be. It is common knowledge to all children capable of appreciating the existence of the power of growth in an animal that plants grow. Even the city-dweller has seen a geranium increase in size, or nasturtium seeds grow, flower, and die in one of those window-boxes almost universal at the windows of model dwellings so common in every part of London—those window-boxes that caused a well-known novelist to observe that it almost made one feel that mankind, having been turned out of a garden at an earlier stage of his existence, was eternally trying to get back again. Children will appreciate, then, that the geranium, like the puppy, grows.

But growth alone does not constitute evidence of life. Crystals grow; they increase in size by taking to themselves small quantities of substances of exactly the same composition as themselves—they grow by accretion. But growth as the geranium and the puppy grow is a different thing from the growth of the crystal, and this difference is appreciated by the very young child. Puppies and geraniums grow by absorbing, in ways that will be explained later, substances which they add to their own bodies by much more elaborate processes, which we call intussusception. So we find one characteristic of life that is common to plants and animals and is peculiar to them, and stamps both as endowed with life. Breathing, eating, and moving, and, to add another very important characteristic of life, the reproduction of their kind, cannot so readily be demonstrated as being common to both plants and animals, because a certain amount of preparation and apparatus is required. But it is part of the object of these efforts to set forth the evidences of life as they may be presented to children, and the apparatus necessary is such as is easily available in almost any house and should certainly be found in any school, because (and it is sad that such a reason should be adduced in any question affecting education) it costs, even to-day, only a few pence. Children can, however, at the outset be told that plants as well as animals breathe, and that they would die if they were covered up so that no air could reach them ; that they eat, and will die if taken permanently from the soil or deprived of light ; that they, like animals, move, for sweet peas may be observed to wrap their tendrils round their supporting twigs ; while it is known to the youngest child who has ever lived in a house with a bitch or a lady cat that puppies and kittens do from time to time appear, and that garden plants grow seeds that themselves, when planted, develop into plants like their parents. These characteristics will, however, be demonstrated at a later stage. Further, there are those responses to stimuli, such as the turning of foliage toward light, which may be compared to the movement of an animal toward warmth, which children will readily accept as evidences of life in plants.

Clearly, then, both plants and animals are endowed with life. Is there any difference in the nature of the two kinds of life ? Is an animal alive in a different sense from that in which a plant is alive ? The answer is that there is no clearly defined line between the animal and vegetable kingdoms. It is unfortunate that in the past so much has been written about the differences between animals and plants. The truth is that one animal may differ more from another animal than it does from a plant ; we shall learn more about life itself by recognizing this fact than we shall by expatiating on the differences between the two great groups into which living things are for convenience divided. For convenience it is permissible to say that most animals feed by taking into their bodies complex substances, which they break down into forms in which they can make use of them as food, and that most plants, on the other hand, are obliged to find their food in a condition immediately available as such. The modifying ' most ' in each case is, however, essential for accuracy's sake, for both botanists and zoologists claim certain organisms ; but while in the past hot discussions took place as to the justice of the respective claims, we are, with advancing knowledge, finding a more tolerant view adopted by both parties, and a recognition that the ownership of such organisms is vested in both, and that they are necessary to both to enable them to pursue their investigations into the mysteries of life. For those who would like to go more deeply into the subject at this stage, the study of *Euglena viridis*, a protozoon, and Convoluta, one of the flat worms, may be recommended—the former being an organism that lives as a plant by day and as an animal by night, the latter one that lives as an animal for part of its existence, as a plant during another part, finishing its span of life as an animal. Lest the reference to Convoluta be misunderstood it seems desirable to add that while its animal nature is undoubted its manner of nutrition during part of its existence is so extraordinary as to call for considerable caution on the part of any who would too readily erect a barrier between plants and animals on the ground of differences in methods of obtaining sustenance. Classification is an interesting study, and, indeed, we should know little of either plants or animals without its assistance, but it does not enable us to place organisms into so many labelled bins that are watertight and inelastic. This is due to the certainty of the common origin of all living things, which should be borne in mind, but it opens up the great question of evolution, which cannot adequately be dealt with within the limits of a work of this type, though it will be desirable briefly to consider it at a later stage.

Of what do living things consist ? What is the chemical substance in which life is manifested ? When we think of a plant we recognize different parts, and may be inclined to regard these parts as composed of different substances. We recognize green leaves, brown stems, white or, sometimes, gaily coloured roots, and these are not *obviously* composed of the same material. If we peer deeper into the matter we may recognize fibre, sap, things that are not obvious on the surface. When we turn to animals we instinctively think of flesh (or, as we must call it, muscle), bones, hair, skin, blood. But these substances must be composed of elements, which we think at present cannot be more finely divided, except into atoms and electrons and protons. However, we are going along too fast. The fact is that every living part of an organism (and bone in animals and fibre in plants are living tissues in the live object) consists of protoplasm, a substance that seems to be the essential home of life, or rather the only substance in which life ever exists.

Protoplasm consists mainly of six elements: carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus—consists mainly of these, but also of very many more elements, yet so small in amount that these six constitute by far the greater bulk. Now protoplasm is very much like the uncooked 'white' of an egg. If we look at it under a microscope with a *very* high power, that gives enormous magnification, we shall see it as a clear substance apparently built up of a vast number of bubbles. Beyond this we have not, so far, been able to go. A microscope, it should be understood, does not show us what things are like; it only shows us more what things are like than we can tell with our unassisted eyes; but with every improvement in optical science we get nearer to knowing what things really look like.

It has been necessary to say this much, but it will be developed as we go along. The next point is that all living matter is built up of a number of cells. The study of the cellular structure of living organisms is a science in itself, so we can deal but very imperfectly with the cell now. The cell, however, is the unit of living substance, and all living parts of an organism consist of one or more cells each of which is alive, moves, feeds, grows, and reproduces itself. These cells are very tiny, and generally cannot be seen as individuals except by means of a microscope, though, as they exist in most of the objects with which we shall deal, a comparatively small magnification (×80) is sufficient to show them and their structure. Every cell contains a nucleus, and may contain other bodies, as we shall see. The nucleus is necessary to the general health of the cell, and for its capacity to multiply, *i.e.*, reproduce itself, or, as we say, in order that it may segment. The simplest animals and plants consist each of a single cell with its nucleus, but in some of the simplest plants the nuclear substance is not very clearly defined and is somewhat mixed up with the rest of the protoplasm of the cell.

II. NEST AND EGGS OF THE YELLOW-HAMMER (*Emberiza citrinella*)

Photo C. H. Royston

We cannot study nature for long or very intently without realizing that things are not what they seem, or, in other words, that objects that appear to possess certain characteristics are found not to possess those characteristics when we look more deeply into them. For instance, if we examine a piece of highly polished metal with the naked eye we are impressed by its smoothness, but if we examine it by means of a simple, low-power lens we find that the wonderful polish consists of innumerable scratches, and that the higher the polish the greater are the number of scratches. Again, some things that to the unaided eye appear to be very simple are shown by a lens to be highly elaborate or complex in structure. A simple instance of this is a blade of grass, which, to the eye, appears to have a smooth edge, but which, under a lens, is shown to have a jagged and toothed appearance. It is obvious, therefore, that in our study of life we must be assisted by certain apparatus, the most essential of which is a pocket-lens. Such lenses are well known and need not be described. Quite good lenses, even to-day, can be had for one shilling and upward. The teacher who is taking his work seriously will feel the need of a microscope, which is now increasingly found in schools. But we can learn quite a lot about life without a microscope, though if we do not possess and have not access to one we must take the word of those who use such aids as to certain facts. Further, we may see things, and yet they may not impress themselves sufficiently upon our consciousness to enable us to explain afterward what we have seen. Experience shows that we remember best things we have drawn. If we have ever drawn a plant we shall have no difficulty in describing afterward the shape of its leaves, or the manner in which they are attached. The apparatus we use will be of the simplest character, because it is desirable that experiment and observation should be carried out by as many as definitely denotes that organism as being a plant. The green matter is called chlorophyll, and is contained in a number of bodies known as chloroplasts. It alone is responsible for the green colour of the cell, and, in fact, for the colour of all green plants. The interior of the chloroplasts consists of protoplasm, in which the living processes are specially present, while the smaller body is the nucleus.[1] The clear spaces are known as vacuoles.

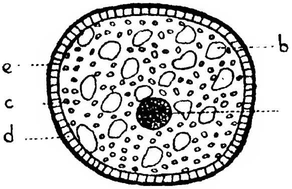


FIG. 1.—A unicellular plant such as Protococcus, highly magnified and somewhat diagrammatic. (*a*) Nucleus. (*b*) Vacuoles. (*c*) Starch granules. (*d*) Layer of chloroplasts containing chlorophyll. (*e*) Cell wall, consisting of cellulose.

Now it does not always happen that one of these plants consists of a single cell. Sometimes the individual consists of a small colony of several cells, forming a living whole because the cells are connected by tiny strands of protoplasm uniting them through small orifices in the cellulose of the cell wall. However, the normal plant we shall find to consist of a single cell only, and it is as a single-celled plant we are going to consider it, because we want to view plant life in its simplest form, or in the simplest form in which we can conveniently study it. There are simpler plants, but they are not green plants. We may at this stage mention that the simplest plants of all are bacteria, the cause of so many diseases, yet, so far as some of their species are concerned, the guardians of our health. It cannot be too clearly understood that all bacteria are not harmful, any more than all reptiles are harmful—indeed, the great majority not only do no harm to us, but are actually necessary to good health and to many of the processes by means of which we obtain our food. We shall be able to discuss other kinds of plant afterward, however, and are now concerned with those plants which possess a green colour, because the green colour is an important factor in the feeding of plants that possess it : most of the plants with which we are ordinarily familiar, from the mighty oak right down to the humble organism with which we are now dealing, do possess this green colour.

---

[1] See p. 28.

We must give our plant a name, so we will call it Protococcus. One of the most important things about it, after its simplicity, is its green colour. We have seen that this colour is situated in the chloröplasts, and we now know that the green matter itself is called chlorophyll. The exact nature of chlorophyll we do not properly understand, though its chemical composition is known, but it is with its functions we are concerned. Why does so much living matter contain this green colour ? It is a question any child may ask, and he should early have realized that so far as nature is concerned there is a reason for everything. Our single-celled protococcus, like its neighbour the oak-tree, requires its chlorophyll to enable it to make use of the stores of food by which it is surrounded. The salts contained in the water that flows over it from time to time, the air, and the sunlight that is so closely associated with the chlorophyll give the plant all that is necessary for it to live its life and fulfil its destiny. Into the details of all this we shall inquire in the next chapter, when we deal with a plant that conforms more closely to the accepted idea of a plant ; indeed, such unicellular creatures as protococci do not enter very largely into our lives as a rule, and they have been introduced here because we can most easily gain an insight into living processes by examining them in simple organisms. We do not commence the study of arithmetic with compound interest, and we should be bewildered if we tried to understand living things by choosing highly complex and specialized organisms. The single-celled plant, however, serves to show us in how simple a form life may exist. It is in some respects a highly specialized plant, but it is specialized in the direction of simplicity, getting its living in a humble manner, asking very little and giving very little. On its debit side are found water, air, and light ; on its credit side it affords nutriment for plants larger, but even simpler, than itself, for it or its kind is host to lichens. A lichen, it may be added, is a plant that does not possess green colour, and therefore cannot manufacture food as a green plant can.[1] It takes advantage of the green unicellular plants and makes use of some of the food they elaborate for their own use.

Protococcus belongs to a group of plants called algæ, which include the seaweeds. They are all simple plants, and many of the larger ones do, in fact, consist of but a single cell. It seems desirable to deal for a moment with the processes of reproduction as carried out by these simple forms. The processes of reproduction are among the most interesting phenomena of life, and it is only by knowing how they are effected in simple organisms that we can ever hope to appreciate the marvels of the processes in more complicated forms. When an organism consists of a single cell it is obvious that the cell has to perform the functions of nutrition, movement when it possesses this capacity, respiration, and reproduction. The advantage a multicellular organism possesses in its numerous cells is the ability to set some aside for one purpose, some for another, and even to allocate some cells to part of a process and some to another part of the same process. The specialization of the cells we shall be able to study most satisfactorily in animals in which we see the existence of flesh or muscle, a muscle cell being a cell in which the capacity to contract with a view to producing motion is specially developed. In single-celled organisms, however, the one cell performs the functions of nutrition and reproduction, and often of movement. We have agreed to leave the question of the feeding of plants to the next chapter.

---

[1] See Chapter III.

The simplest method of reproduction known is by simple division. What was one before becomes two, and two become four, and so on. This is the system adopted by most of the green algæ. But, simple though it be, it is not quite so simple as it sounds in speaking. We have already referred to the nucleus, that inner part of every cell, which is, even though the whole organism consist of one cell, in some way specialized ; we know that the protoplasm of which it is composed is somewhat different from the rest of the protoplasm of which the cell consists, for if certain stains are introduced into the water in which we have placed our organism we find that the nucleus absorbs more of the stain than does the other protoplasm. When division of the cell is to take place it is in the nucleus that the first signs are manifested. For the information of the teacher, who can profitably explain the processes to children capable of understanding them, it seems desirable to give some details, because these divisions are constantly going on in all living matter, including our own bodies. The normal condition of the nucleus is that of a spherical body, but when dividing it elongates and develops a long thread or skein ; this latter breaks up into pieces of equal length, which interlace in a bewildering fashion. What is now being described can be seen, it must be understood, only by the assistance of the higher powers of a microscope. Notwithstanding the apparent confusion that reigns at this stage, the nucleus is carrying out an orderly series of phenomena. The pieces of the skein now become arranged across the centre of the cell, while some much finer threads, different in composition, arise at the opposite ends of the cell and connect up with the pieces of the skein, forming a ‘ spindle,’ as it is called in recognition of its general appearance. Then each of the thread-like pieces—we may as well call them by their proper name, chromosomes—divides into two pieces lengthwise, which move toward the opposite ends of the spindle, where, crowding together, the two groups each form a new nucleus.

In the foregoing account reference to the part played by the centrosome, a very small body found in most cells in close association with the nucleus, has been omitted for the sake of simplicity, but it is hoped that reference to the diagram will assist the reader to obtain a clearer idea of the whole process.

Still there is as yet but one cell, though it possesses two nuclei, and single-celled organisms possessing two nuclei are sometimes encountered. How then does our cell become two ? If we are patient, for the remainder of the story takes longer in action, we shall find that a layer of protoplasm passing through the centre of the cell becomes differentiated into cellulose, which, as we know, is the substance of which the cell wall of the unicellular green alga is composed. So the division is complete, and one cell has become two.

This question of cell division is one that is of so great importance to a clear understanding of so much in nature that it is worth while taking the trouble to understand it. The expression ‘ understand ’ is used in a relative sense only, and in the sense in which we ‘ understand ’ the movement of the earth round the sun. We know how it goes, we know the results ; but we do not know what causes it, or, in the case of the cell, what stimulus provokes the action. We shall have more to say later on this subject, because the process is common in biology, but in other reproductive processes the action is complicated by the preliminary conjugation of two cells, one drawn from each parent; after conjugation, however, the process is as described, and in

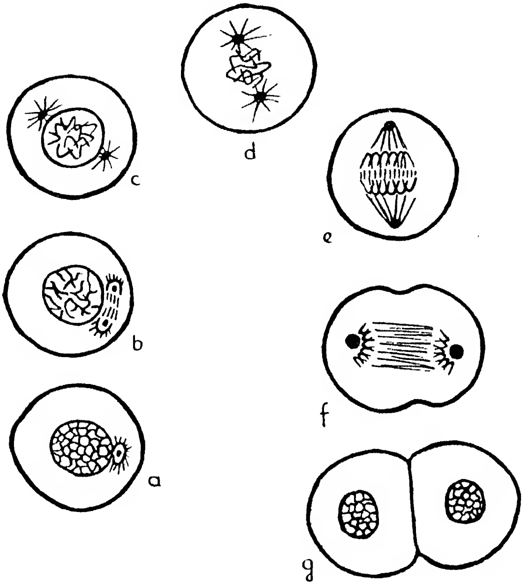


FIG. 2.—A diagrammatic representation of an animal or vegetable cell, much magnified, dividing. (*a*) Cell, showing nucleus and centrosome. (*b*) Centrosome divides, and the parts move to opposite sides of nucleus. The network substance of the nucleus is breaking up and forming a thread. (*c*) The thread divides into pieces of equal length called chromosomes. (*d*) The nucleus has disappeared, and the chromosomes appear to be free in the body of the cell. (*e*) A spindle forms in the centre of the cell, each chromosome divides into two parts which separate, and half the pieces move to one side of the cell and half to the other. (*f*) The chromosomes surround the centrosomes, while a cell wall forms across the space previously occupied by the nucleus. (*g*) The completion of the division.

the most elaborate plant or animal every cell of the millions of which the body is composed contains part of each of the two original cells from which it had its origin.

In some of the green algæ reproduction is effected by the breaking up of the cell, but not directly into two new cells. By the division and subdivision of the nucleus the original body is divided into a swarm of minute cells, forming complete entities within the original cell wall, which, in due course, ruptures, liberating the young like a cloud of spores. If the plants live in the water each of these will be found to be provided with a pair of whip-like processes, called flagella, by means of which their owners lash themselves along through the water until they come to rest where conditions for their development and growth are suitable. If they are land plants the spores are carried by the wind to rest in spots where they either perish because of unsuitable environment or, in a suitable situation, develop and grow. In some cases two bodies coalesce, and then each of the young partakes of the characteristics of both parents.

Reference has been made to the possession of flagella by immature forms of green algæ and to the movements resulting therefrom, and it is therefore unnecessary to refer to certain free-swimming plants such as the diatoms, of which it is estimated there are probably ten thousand species. Seen under the microscope, diatoms would at first glance be supposed to be animals. It has always been assumed that plants are plants and animals are animals, and characteristics have been ascribed to each; if we adhere to our definition (p. 26) we must place living organisms in one kingdom or the other whenever it is possible so to do. Our diatoms, because of their method of feeding, clearly go into the vegetable kingdom. But what of the more difficult cases? The interested reader is presented with one, *Volvox globator*—the revolving animalcule—to study for himself. He will not get far, if his goal is a decision on the matter, but he will be provided with food that will give him furiously to think.

We have examined one simple unicellular plant and have briefly considered others. Let us now proceed to apply the same investigation to an organism that is indubitably an animal, which botanists have never claimed any more than zoologists have ever claimed Protococcus. The animal is known as Amœba : its common name is too ugly—the slime animalcule. It is not so pleasing to the sight or so interesting in many ways as are comparatively close relations, but Amœba cannot be avoided by any student of nature : hardly a book on nature has been written without reference to it. Unfortunately it is small, smaller than our unicellular plant. But it would be unfair to pass it by, because the people who many years ago were looking for the origin of life, and who believed that life was evolved spontaneously from the ' slime ' existing in damp places, would, had they possessed microscopes and known of it, have hailed it as evidence of the truth of their faith. Amœba is not so small as not to be seen with a very low-power microscope, and when it has once been detected it can be seen even with a hand-lens, but it cannot be studied without a microscope. Although abundantly common, experience shows that it cannot always be found with certainty. However, a minute portion of mud from stagnant water, spread on a glass slip with water and examined by means of a microscope, generally reveals its existence. It appears as a speck of raw white of egg, but if it is watched carefully it will be seen to move. Its manner of progression is interesting. It does not walk—it has no legs ; it does not swim—indeed, it has no organs of propulsion. It flows along. If we filled with water a bag made of thin rubber and flung it on a table it would assume a round shape something like a piece of dough ready for shaping into a loaf of bread, and would give a very fair idea of what Amœba looks like in a state of rest. We can carry our description farther by pointing out that if we pressed a hand into one side of our rubber bag the other side would be forced out to the same extent, though not in the same outline, as the side forced in by the hand. This would give us a rough idea of the appearance of Amœba in motion. Actually it progresses by pressing out, in the direction in which it is moving, a number of blunt processes from the substance of its body, the movement being effected by the contraction of the hinder part. But it is necessary to explain that the word ‘ contraction ’ is used in a loose sense, since Amœba has no specialized tissue of a contractile character in the sense in which muscle cells possess it. The whole animal consists of but a single cell. When we examine it under a higher power we see clearly that its structure is as simple as it can be. There is a thin outer rind filled with a substance consisting of the characteristic protoplasm, which, as we have said, appears under a very high power to consist of a mass of bubbles filled with water. There are no organs—no mouth, no appendages, no protective shell, no definite cell wall. The animal assumes any shape at will, and drawings made of one individual at intervals of a few minutes bear no resemblance to one another. But we may, especially when we have introduced a staining fluid into the water on the glass slip, observe an obvious nucleus. We shall, further, see various other bodies, in all probability minute portions of

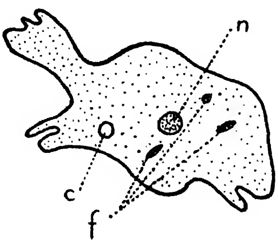


FIG. 3.—Amœba, highly magnified. (*c*) Contractile vacuole. (*f*) Food particles. (*n*) Nucleus.

nutritive material which the animal has ingested by wrapping itself round them. We may actually watch this process of feeding. Amœba not only has no mouth ; it has no alimentary canal. When it encounters a substance from which it can extract nourishment it wraps itself round it, and the substance that was outside its body is then seen to be inside. When all the nourishment has been extracted the foreign substance is ejected by reversing the action, if so simple a process can be dignified by language that implies an orderly series of phenomena—it just leaves it behind in the same casual manner in which it picked it up.

But Amœba contains something else that we shall see if we observe it long enough : we shall see a clear space, which is known as the contractile vacuole, gradually growing, suddenly disappearing, and growing again. Possibly it is partly excretory in function—that is to say, it serves the purpose of eliminating from the living body those unliving substances that are the waste products of living things. These substances, it has been suggested, may possess a strong affinity for water, that is, possess the power of attracting water to themselves, which chemists know that certain materials do possess. When the vacuole has attracted as much water as it has accustomed itself to hold, it bursts, and the contents are discharged into the surrounding water, when the process of enlargement begins again. But no contractile vacuole is found in any species of amœba inhabiting sea-water, and we are led to wonder whether its primary purpose may not be that of a regulator of osmotic pressure, enabling the animal to resist a tendency to dissolve itself into the surrounding water.

Except that it is the seat of the mystery of life, there is very little to know about Amœba. It is so simple in structure, in its manner of living, even in its appearance. Nevertheless, there are several species, which can be recognized and named, and we know their characteristics. The form we meet with most commonly reproduces itself by simple fission, the nucleus dividing as has been described, and the whole body becoming two complete amœbæ in due course. Instances have been observed in which, owing to the drying up of the animal, it has formed itself into a cyst by secreting a cell wall, when the return of happier times in the form of rainy days has restored it to active life, and the contents of the cyst have produced not the original animal, but a crowd of tinier amœbulæ, which have afterward grown up into adult animals. Some kinds of amœba employ a more elaborate system of reproduction, more on the lines of systems adopted by higher organisms, when two separate animals fuse together permanently and encyst, and then divide into a larger number of young ones, which feed and grow up into real amœbæ. Others fuse in the same manner and produce amœbulæ which feed, but which would never as individuals grow up ; these products of the marriage of two mature animals themselves form unions in pairs, and having united grow to maturity. Indeed, it is probable that no amœba in existence is the result of long-continued simple division, because Nature has always set herself against reproduction by such methods. It is probable that in those species in which fusion is not *known* to take place it is adopted only at long intervals after the production of many generations by simple fission, and that in consequence the act has so far escaped observation. The two animals taking part in such a union are in every respect similar, so far as we can tell ; they do not exhibit any sexual differences, yet it is clear that since the fusion is complete each of the young partakes of the substance of both parents.

Something should be said as to the fusion of the two cells to form one, because we have considered fully the division of one cell to form two. In the latter case we have a single organism to deal with, and we have examined the process by which it divides. But when the union of two organisms precedes segmentation (as the division of a cell into two or more is called) an equally interesting process takes place. We have remarked that Nature is opposed to the simple form of reproduction, and the statement seems to be justified by its rare occurrence both among plants and animals. We have suggested, too, that organisms that are supposed always to adopt the simple process are probably those we have not been able so fully to watch. We do know that experiments have shown that some that were supposed never to fuse died out when they were kept in conditions not conducive to fusion, but it is not yet clear whether their decline and destruction were due to exhaustion that might have been overcome by conjugation, or whether they were due to the toxic effects of their own excretions. One animal in particular, the slipper animalcule (*Paramœcium*), which was thought always to reproduce itself by simple division, was afterward discovered to be dependent, after many generations, upon a temporary union of individuals. The necessity for it can, it seems, be controlled by the paucity or abundance of nutritive material. It would occupy too much space to go thoroughly into the experiments that have been made, and it is rather beyond the scope of an introductory work on nature study to do so. Opinion is even yet much divided as to the need for conjugation or cross-fertilization. The most that the writer can hope is that the reader may be led to appreciate that a great deal may lie behind the practice of ‘ introducing new blood ’ by this discussion of the life histories of organisms that do not possess ‘ blood ’ in the full meaning of the word.

The slipper animalcule is, like Amœba, a single-celled animal, belonging to an order which is called Infusoria because its members are found in vast numbers in any infusion of organic matter. There is not space in which to deal with its many interesting features, and it is introduced here only to illustrate a stage in the development of reproductive processes. For many generations it reproduces itself by simple binary division, but after a time the necessity or desirability for conjugating in pairs seems to arise. The slipper animalcule possesses two nuclei, and is therefore better endowed in this respect than Amœba. One of the nuclei is much bigger than the other, and when the animals pair their large nuclei disintegrate and disappear. It must be understood that the animals do not lose their individuality when they pair; they remain as separate individuals merely in juxtaposition along their ventral surfaces. The larger nuclei having disappeared, the small one in each paramœcium divides into eight pieces, and seven of the pieces are ejected from the bodies of each. The remaining one now divides into two, and one part passes into the body of the other, which gives in return one of its own. Each of the animals, therefore, still has two small nuclei, one of which is of its own substance and the other of the substance of its neighbour. The nuclei in each now fuse, and the individual

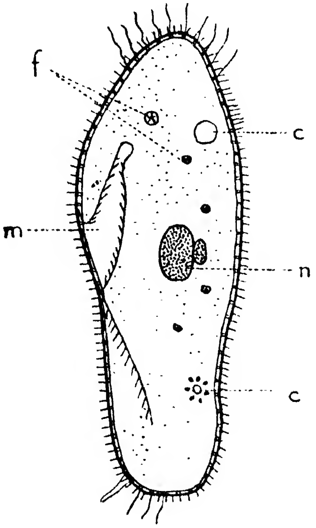


FIG. 4.—Paramœcium, highly magnified. (*c*) Contractile vacuoles. (*f*) Food particles. (*m*) Mouth. (*n*) Nuclei.

paramœcia, each with one nucleus, separate. If we continued to watch either of them we should find that its nucleus divided, and that the two nuclei so formed again divided, so that at this stage each animal had four nuclei. Our interest would now be stimulated, because we should see that the whole animal was dividing transversely into two and forming two complete individuals, each of which possessed two nuclei; and, further, continued observation would show that as each went its own way one of its two small nuclei would grow into a large nucleus, while the other would cease to grow beyond the ordinary size of the smaller nucleus of a normal specimen. Later our paramœcium, having fed and grown, would commence to propagate its species again by simple division until, many generations having passed, the process of conjugation might ensue once more.

This somewhat elaborate description of an intricate but very interesting process is not out of place in a chapter devoted to simple forms of life, because it shows that even at this early stage in the development of the kingdom of life a process takes place that is not very different from the process as exercised in much higher organisms. It can be studied in simple forms very profitably, because it is, so far as we can see, divorced from passion and personal considerations that are the concomitants of the associations of higher animals. These associations are a solemn mystery that have aroused in some people feelings of reverence and awe such as have precluded their being openly discussed, while to others they have been the subject of such perversion and misrepresentation that many have shrunk from alluding to them at all. On the one hand, ordinary functions of life have been treated as unclean things; on the other, as mysteries so profound that they may not be referred to in speech. And the resulting chaos has served only to push back into the darkness things that are sufficiently beautiful to be worthy of the closest study, for they show us one of the means which Nature has devised for attaining its end, whatever that end may be. We cannot claim at present to know what the end is. That it is something more than fruition and multiplication can hardly be doubted, for often and often some particular part of the globe has been stocked beyond all reason, so that the pressure upon space and food has led to extermination, or at least to wholesale reduction in quantity.[1] It is with the conspiracy of silence we are concerned, and against it the parent, the priest, and the teacher must ally themselves. One of the chief objects the writer has in view is to supply the means, or at least to indicate the means, by which the conspiracy may be dissipated.

---

[1] See Chapter XV.

CHAPTER III

A TYPICAL PLANT

WHEN we speak of an animal a horse or a dog or some such organism immediately suggests itself to our minds ; we do not instinctively think of Amœba or Paramœcium. The reason is that we do not ordinarily see these smaller beasts. Similarly when we speak of a plant we do not immediately turn our thoughts to protococci or diatoms ; we visualize a cabbage, or a carnation, or, if we are in the habit of studying nature, perhaps an oak-tree. So when we *write* of a typical plant we mean not only a plant that is typical of plants, as representing the shape and performing the functions of the majority of the organisms that by common acceptance are regarded as plants, but one that would immediately suggest itself to any ordinary person who is in the habit of seeing gardens if not of working in them. A plant that suggests itself is the wallflower (*Cheiranthus cheiri*), and as an object for detailed study perhaps we could not choose a more suitable one, for the wallflower is as commonly met with in this country as any plant. It exists as a plant throughout the year, and, further, it is more constantly in bloom than any that suggests itself at the moment. The writer has had wallflowers in bloom in his garden from February to November. Such protracted fecundity, it should be explained, is not normal ; there is not space in which to go into all the conditions that produce it in individual cases. The peculiarity is a useful one, in that it makes the wallflower a particularly suitable plant for our purpose. But, allowing for such inevitable differences as exist and differentiate one plant from another, it may be added that other plants, namely, the ordinary ten-week stock (*Matthiola annua*) and shepherd's purse (*Capsella bursa-pastoris*), would answer our purpose equally well, because these are closely allied to the wallflower, and their leaves and other organs are similar. What is said, then, of the wallflower can be easily followed if, in its absence, the student has access to either of the foregoing substitutes. The advantage of having the object itself easily available cannot be over-emphasized. Children may learn nothing from a nature-lesson given in the absence of the object itself, but they will learn much if they are set to examine the plant, even though the teacher may have little knowledge himself. Care must be taken, therefore, that a plentiful supply of plants is provided, and the teacher cannot afford to be satisfied unless every child is provided with one. Fortunately supplies of wallflowers are readily available, and if the school has a greenhouse, or even only garden plots, a supply may be ensured at the cost of but a few pence and the necessary foresight by the purchase of a packet of seeds, which, planted in a heated greenhouse a few weeks previous to the occasion on which the plants will be needed, will provide all that are required. In the absence of a greenhouse the seeds should be planted in the open during the summer, and plants will then be available from the late autumn onward, though they will not flower till the following spring. In practice it will generally happen that the class is provided with immature plants; and these will serve our purpose quite as well, because, after the children have been taught the elements of the plant's mode of life,

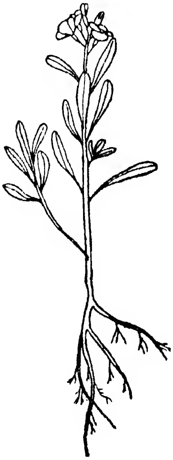


FIG. 5.—A wallflower plant.

the lesson of the sanctity of that life can be inculcated by explaining that no life should be destroyed unnecessarily, and that even though it may be necessary at times to deprive an organism of its life in a good cause—such as that of learning—it should be absolutely unavoidable if it is to be justified. The plants can be kept alive in water for quite a considerable time, and it is a good plan when they have fulfilled their purpose as unflowering plants to allow each child to plant his own in his plot or in the garden of his home. It will probably establish itself and, in due course, bloom. Moreover, such a plan crystallizes the interest that has been aroused.

We will assume, then, that the class is well provided with plants. What does each child see ? Probably more than we do, but, to make sure that he sees as much as possible of what is to be seen, he should be made to draw the plant on paper. Children will recognize the leaves, the stem, and the root ; the more observant will go farther. Perhaps the best plan is to describe what should be shown. If the class can first be shown the plants growing in the soil this will be all to the good, and better still if they can be allowed themselves to dig up the plants, having previously been warned to dig all round the roots first and thoroughly to disturb the soil so that the plants do not lose their delicate rootlets by forcible withdrawal. The stem is more or less green, and becomes more completely green the farther from the root we examine it. The part of the plant that lives below the surface of the soil is clearly marked, and it should be pointed out as an important characteristic that this part is not green. The upper part is the more attractive in appearance, and it will first command attention. At a short distance above the point at which it emerges from the soil will be found the first leaf. Observe and point out that it is flat. The leaves are thrown out at frequent intervals, and at different points on the circumference of the stem, *i.e.*, they do not overshadow one another. There is no stalk, the leaf being joined directly on to the stem of the plant, the point of junction being called the leaf axil. The axil is important, because it represents a potential side shoot. In some of the axils we can find the side shoots actually in existence, growing-points which develop into parts like, but smaller than, the main shoot itself, each representing embryo leaves and flowers. The part that is normally below the surface of the ground is almost white, if it has been sufficiently washed to free it from the soil that is held by the filaments of the root. The root is more branched than is the upper part of the plant. The main root should be noticed, and the side roots branching out therefrom, whence grow finer rootlets. At this stage we will assume that the plant is not in flower, and we can proceed to make some experiments to ascertain how it lives and performs those functions of a life that is, we have observed, so similar to the life of animals.

We know that wallflowers do not eat animals and other plants. Yet we know that they grow. Probably we have watched our specimens develop from the seeds we planted in the previous summer. We can only discover the manner in which things come to pass by surmising that they do so in a certain way and then testing our conjecture, *i.e.*, by hypothesis. Plants cannot add to their size and weight by any miraculous means ; they cannot, that is to say, increase their substance unless they diminish the substance of something else. We eat food, and utilize the assimilable part of it to build up our bodies and to make good what is used up in our daily work. We cannot build a boat out of nothing ; if we build it of wood there is a tree the less, if of iron there is a hole in the earth from which the iron was taken. Our hypothesis is, then, that the plant increases its substance at the expense of something else, and since we do not see it eat any-

thing with a visible mouth we will assume that the roots have something to do with nutrition. And we should naturally look there, because, on reflection, we should ask whether the roots were necessary to the plant unless they did perform some such function. We know by our own experience that everything in nature has a purpose, and that if it does not exercise the purpose for which it was provided it deteriorates and may eventually atrophy and die. Those who have suffered an injury to a limb and have had in consequence to rest it for several weeks know how that limb wastes to thinness, and how it begins to show development again as soon as we are permitted to use it. Now, as regards the roots of a plant, it is true that the roots are necessary to support it, to anchor it in the ground ; if they did not exist the plant would be blown away. But would such elaborate roots as those possessed by the wallflower be required ? Do the finely branched roots help the plant to get a firmer hold on the soil ? Presumably not, or to a very small extent only, for if we forcibly drag a plant from the earth we find that we have pulled off all the fine roots, and that only the main root and the large side roots remain. Probably the roots act also as organs of nutrition. It can readily be demonstrated that they do.

Let us examine the root in detail, after it has been washed in water as cleanly as possible. Children should do this washing for themselves. By careful observation it will be seen that there are fine hair-like growths on the rootlets. These may be seen much more clearly by means of a simple magnifying glass. Such lenses will be constantly needed, and children should be encouraged to buy them for themselves on the assurance that they will last them all their lives and be a constant joy and source of interest. It is a fact that those who have once become accustomed to the use of the pocket-lens would be as reluctant to sally forth on a ramble without their lenses as without their watches, and, given the choice, would prefer to take lenses. Most parents would willingly equip children in whom an interest has been developed. So we will direct the class to examine the rootlets with their glasses, and they will see these hairs quite distinctly. It is very important that they should be seen, because they play an important part in what we are going to discuss. Attention may be drawn to the various forms of roots, but whether they be ‘ tap ’ roots such as the carrot has, or much divided roots such as those of our wallflower, they all possess one function, though some also possess others.

The root having been thoroughly examined, attention should now be given to those other parts of the plant which we passed over rapidly. If a wallflower plant of mature age—a second-year plant that was started early in the previous year—is taken it will be noticeable that just as the root had branches growing out from the main root, and these possessed rootlets, so the stem bears side shoots, which also possess leaves ; indeed, regarding the leaves as comparable to the rootlets, the part of the plant that lives above ground will be observed to bear some resemblance in arrangement to the part that lives below ground. The comparison must not, however, be pushed too far. It may be noticed that side shoots grow out only from the axils of leaves ; low down on the main stem, or even on the lower side shoots, side shoots may be observed that show no leaf marking their point of origin, but careful examination will disclose that there is a scar where a leaf had existed before it became detached from the plant. It will be noted that the side shoots nearer the top of the plant are shorter and less developed than those lower down, and very often each is represented only by a tiny green bud in the axil of a leaf, which may in ordinary course never develop. But they are part of Nature’s plan of providing against accidents, and if the developed side shoots were broken off these buds would swell and grow into side shoots themselves—they are potential side shoots, provided against possible accidents that would prevent the old shoots from maturing. We shall see later that the object of the side shoot is to bear flowers to fulfil the functions for which the whole plant came into existence. The end of each side shoot, like that of the main shoot itself, resembles a green rosette consisting of tiny leaves, and it is here that the buds, flowers, and seeds will ultimately develop.

A leaf should now be examined in detail. If it is held up to the light its structure will more easily be seen, for the leaf is somewhat thick and fleshy. A strengthening rib will be observed lying along the centre from the point at which it was attached to its stem to the apex, and extending from points along this rib will be seen the fine lines that have been called veins from their similarity to the veins of the human body. This similarity is one worthy of comment, because though they do serve to strengthen the structure and enable it always to extend its greatest surface to the sunlight they also act as water channels, for they consist largely of those water pipes or bundles which are seen quite clearly in the stem of a young plant. We could, by cutting across the stem of a wallflower, and examining the cut surface with a lens, see these bundles of water vessels ; one of the plants in which they appear most clearly is the sunflower. If a young sunflower plant be cut across we can see them arranged in a circle, and by stripping away the skin in a downward direction it can be shown that the vessels run the whole length of the stem, and even that they are extended into the stalk of the leaves and form the veins. It is along these vessels that the water most easily passes, because they consist of elongated cells specially formed to facilitate the passage of water. We shall later refer to the root pressure by means of which the water is forced up, but there is another force also in operation. The leaves of the plant, and especially the under sides of the leaves, possess great numbers of tiny pores from which the water is being continuously given off in the form of vapour, and the giving off of this moisture attracts the water sucked up by the roots. This process of giving off water is known as transpiration. That it actually takes place can be demonstrated by enclosing a leaf or a small branch of a growing plant in a glass tube and closing the mouth of the tube with cotton-wool so as effectually to prevent the entrance of moisture without exerting too much pressure on the stalk of the leaf or branch. The interior of the tube will rapidly become clouded, and after a short time the minute particles of water of which the cloudiness is composed will run together and produce drops. This is an easy experiment which cannot fail if only ordinary care is taken.

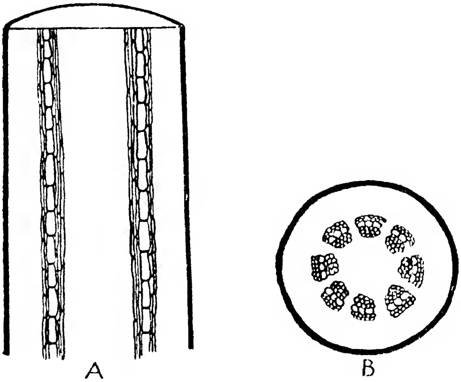


FIG. 6.—A plant stem in (A) longitudinal and (B) transverse section, showing the vascular bundles, consisting of specialized cells, by means of which fluids pass up to and down from the leaves.

A very good idea of a typical plant should by now have been obtained, and what has been learned regarding the wallflower can be applied equally well to nearly all green plants, be they small—such as, for instance, the little lobelia found in precise and formal flower-beds—or mighty forest trees. The different forms adopted by plants serve their special purposes and bear direct relation to their work in nature. For they work for their living, just as we do, and are constantly striving, as we strive, to better their positions in life and to fulfil the purposes for which they exist. In many cases life is a hard struggle, but all life exists and is carried on only on condition that the organism in which it is implanted works, and work consists usually of the utilization of the beneficent circumstances to overcome the action of adverse circumstances. If the conditions were all beneficent the organisms would deteriorate, and might die out, for progress results from struggle, and the strong, virile plant has attained its strength just as the ' strong ' man of character has attained his personality by determination of purpose and by overcoming difficulties and building up successes from his battles. We shall find many examples of this in nature, even among the ' lower ' animals and plants, as we shall if we look round us and observe the people among whom *we* work.

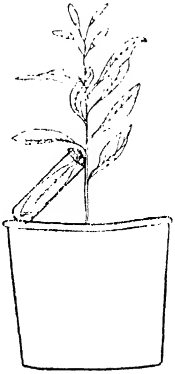


Fig. 7.—An experiment to demonstrate the transpiration of water by a growing plant. One of the leaves is enclosed, by means of a wad of cotton-wool, in a tube, which collects the water given off.

If the wallflower plants we are examining have been for some time out of the ground they will be showing a tendency to droop, and we know by experience that in due course they will wither and die. But if we place a plant with its roots in water we shall see it gradually revive, and if we keep them submerged we shall find it quickly restored to its original flourishing condition, at least in appearance. Now it is not difficult to show that the withered appearance was due to the removal of water by evaporation. We can drive off the water by slow desiccation, by placing a plant in hot sunshine or in a slow oven, but long before it has reached a crisp condition we shall so have diminished its vitality that no attempt at resuscitation will succeed. Our inference is that the water that had been removed by evaporation had been replaced in the specimen we revived, and since only the roots were in water we shall have inferred quite rightly that the water was replaced through the roots. Unless our wallflower plants are quite young, we shall have to choose another subject to demonstrate this capacity of the roots to draw up water. Let us take some young bean plants, each of which has developed one pair of true, green leaves, and cut off the shoot of one just below the leaves. A bead of liquid will form at the cut end. In the ordinary way the bead will dry, and there will be an end of it all. But if we insert one of the bean plants in a vessel of water, so that the roots are submerged but the rest of the plant is in the air, and then carefully cut off the top, removing with blotting-paper the bead that forms, we shall find that another will form and, on its removal, yet another, so that we may be certain that the roots are drawing in water to replace that lost by the ‘ bleeding ’ of the cut end. Plants, then, take to themselves water. Do the roots absorb anything else ? If they do, how do they do it, and why ?

Let us take two more young plants. Young wallflowers will answer our purpose, but quick-growing plants such as beans or peas will do better. Ordinary broad beans can be very readily started on their life's course by being placed in a jar, resting on wet flannel, and the experienced teacher will arrange to have as a rule a good supply of them in different stages of growth always available. Place a growing bean plant in a jar of distilled water so that its roots are thoroughly covered and the rest of the plant is exposed to the air. Distilled water may be obtained from a chemist, or it may be obtained laboriously by boiling water and intercepting and trapping the steam. Distilled water is just pure water and nothing else. Even tap water is not pure, as chemists understand the word, and we must have absolutely pure water for our experiment. Now take an ordinary flower-pot full of garden mould, hold it over a jam-jar, and pour water into it, catching the drainings in the jam-jar. The draining water will be muddy. Pass it through the soil in the plant-pot over and over again until it is reasonably certain that the earth in the pot is so sodden that everything soluble in it has had the opportunity of melting and passing into the jam-jar. Then take another jam-jar, wash it thoroughly and place several thicknesses of filter-paper over its mouth to form a cup into which liquid can be poured, and pass the ‘ dirty ’ water that has been collected in the other jar through the filter-paper into the second jar. Filter-paper has the power of intercepting all insoluble substances, be they ever so small, but allows a passage to water and to any substances *dissolved* in it. The word ‘ dissolved ’ is very important. We often use it loosely, and speak of ‘ dissolving ’ chalk in water when we merely powder the chalk and shake it up in a bottle of water. But the chalk is not dissolved ; it is not in solution ; it is merely temporarily suspended in the water, and sooner or later will sink to the bottom of the bottle as a sediment, leaving the rest of the water clear. If we emptied the bottle of water into the filterbag the water would pass through and the chalk would be intercepted by the filter-paper. But if we put table salt or sugar in water, taking care not to put too much in, it will completely dissolve and pass through the filter-paper with the water. Consequently, the water that passes into the second jar can contain only substances that are in perfect solution. To make quite certain that no solid substances are contained in the filtered water we can pass it through filter-paper several times. The resulting liquid will appear to be quite clear, like the distilled water, when we look down into it, but careful observation will show that in fact it is not quite clear—that it is slightly brown in colour. Having so prepared the water, place in another jar an amount equal to the amount of the distilled water in which the bean plant has been inserted, and put into it another bean plant. It is desirable that the jars should be wrapped in thick brown paper, so that the roots are in the darkness to which they are accustomed. The results of the experiment do not depend upon the use of bean plants—use any growing plants, young wallflowers if these are more easily obtained, but quick-growing plants are most suitable. The two jars should now be placed in a window in a good light, and what occurs should be carefully watched. In two days' time it will be observed that the second bean, the one in the filtered water, has grown more than the other. At the end of a week the difference will be even more marked, but it will not be confined to a difference in size, for it will be obvious to all that the plant in distilled water is ill, starved, and anæmic. Its leaves will be no longer of a vigorous green ; they will be yellowish, and will get rapidly paler. The ultimate result would be death. But we do not teach children to kill anything unnecessarily if we can help it, and they should be told that we know what ails the plant and how to cure it.

We will suppose we did not use up the whole of the filtered water when we placed some of it in the jam-jar. Let us examine it again. Place the jar in which it is contained on a warm stove—not a hot one that will crack it—and allow the moisture to evaporate. When it is all gone we shall find, if we look carefully, a thin, dry coating on the bottom of the vessel, and if we scrape it off, as we can, we shall find it to be a fine powder of a dark-brown colour. We are not sufficiently skilled in practical chemistry, perhaps, to analyse it, but if we hand it to an analytical chemist he will tell us that although it contains many substances in minute quantities it consists largely of potassium, iron, lime, soda, and magnesium. These are mentioned not because they exhaust the analysis of the brown powder, but because we know by experience that they are the substances of most use to the plant.

Probably the amount of distilled water we have in the jar containing the sick bean plant is half a pint. Ask a pharmaceutical chemist to prepare one-eighth gramme each of sodium chloride, calcium phosphate, calcium sulphate, and magnesium sulphate, one-fourth gramme of potassium nitrate, and the smallest quantity possible of ferrous chloride.[1] Put all but the ferrous chloride in the distilled water. Then, dipping a match stalk in a weak solution of the ferrous chloride, let the tip of the wet stalk touch the water containing the other chemicals, but not so much as to allow even a whole drop of the ferrous chloride solution to enter the water. As a matter of fact the bean should be removed temporarily while the chemicals are added to the water, so that they may be thoroughly dissolved and mixed. We shall soon notice a vast change in the health of the plant, which will now possess the same advantages as its neighbour possesses, and they will grow together almost as well as if they were in their natural environment with their roots in the soil. The experiment may be carried farther, and a third plant similarly supplied with distilled water, in which may be placed the same quantity of chemicals, but without the ferrous chloride. The best way of dealing with the experiment is to start three plants at the same time—one in distilled water containing all the chemicals, one in distilled water containing all but the ferrous chloride, and one in distilled water only. The result will be that the plant supplied with all the chemicals except the ferrous chloride will at the start grow as satisfactorily as the one that is supplied with it; but it will soon exhaust its powers, its leaves will become yellow, and, although it will outlive the bean which has distilled water only, in a very short time it will die. The absence of the iron will have deprived it of ability to produce chlorophyll, which, as we have seen, is a characteristic of green plants and essential to their growth. These experiments are of the simplest possible description and may be safely performed by a teacher who may never have dreamed of carrying out experiments in natural science. It is important, however, that the three jars be labelled, so that their identities may be safeguarded. The closing of the mouth of the jar with cotton-wool, or better—as providing efficient protection from direct evaporation—by passing the cotton-wrapped stem of the plant through a split cork, is desirable.

---

[1] The following formula, devised by Dr W. E. Brenchley and employed at the Rothamsted Experimental Station for water culture, may be used in place of that given above: water, 1000 c.c.; potassium nitrate, 1 gramme; magnesium sulphate, 0·5 gramme; calcium sulphate, 0·5 gramme; sodium chloride, 0·5 gramme; acid potassium phosphate (KH_2PO_4), 0·5 gramme; ferrous chloride, 0·04 gramme. For some plants the KH_2PO_4 may make the solution too acid, and the following may be substituted: KH_2PO_4, 0·3 gramme; K_2HPO_4, 0·27 gramme.

We have established the fact that the roots do perform an important function in the nutrition of the plant by experiments that not only indicate this fact, but in addition show us what materials the roots utilize in their work. We have seen that the liquid drawn in by the roots is forced up the stem of the plant, and we shall next proceed to demonstrate that the liquid is drawn up into the leaves, and that the water of which it is chiefly composed is actually breathed off by the leaves in the form of vapour which we can condense. But we must first ascertain, so far as it can be ascertained, how the root draws in the liquid and passes it into the leaves *via* the stem. We can readily understand that if it is a fact that the water is breathed out by the leaves other water will rise to take the place of that expelled. But we know, by the experiment in which we decapitated the plant, that the water is forced up rather than drawn up, and that the passage of the water must be effected by a special force. The force is called 'root-pressure.' How is it generated ?

It is known that certain substances attract water, which will pass through permeable material in order to reach them. If a thistle funnel, or even an ordinary glass funnel, can be obtained the fact can be shown to the class. It provides a useful demonstration that cannot fail if reasonable care is exercised. Assuming the funnel to be available, tie a piece of wet bladder over its mouth very securely and fill it through the narrow end with a strong solution of sugar to the entrance to the point at which the narrow end joins the bowl. Then support the bladder-closed end in a jar of water, so that the level of the water is distinctly below that of the solution in the funnel. A properly equipped laboratory will provide the necessary means of supporting the funnel in this position, but in the absence of a laboratory and its equipment the ingenious teacher will overcome the difficulty. It will be found, and observed by pupils, that the level of the solution will rise, and since it will rise higher and higher into the narrow neck of the funnel the fact that the solution is drawing into itself the water from the jar will be obvious. That it should do so is curious, because common experience suggests that the two liquids would find their own level. Empty the funnel and fill it with water, and repeat the experiment. The level of the water in the funnel will gradually fall until it attains the same level as that taken up by the water in the jar—*i.e.*, some of the water will have passed through the bladder from the funnel to the jar. In the former of the two experiments we found that notwithstanding its higher level the solution in the funnel attracted to itself water from the jar, and this was really what we observed when we noticed liquid rising from the cut end of our plant. The cells of which the root of a plant consists possess a power of attracting water, and with it the salts dissolved therein, which, once inside the root, is forced up along the line of least resistance into the leaves. We know [1] by what route the liquid, or sap as we call it, passes. At the moment we must press on with an examination into the manner in which the wallflowers live.

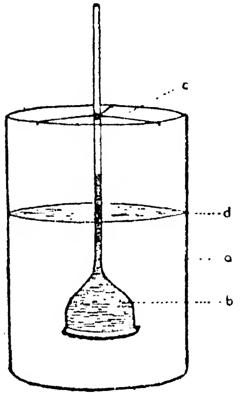


FIG. 8.—An experiment to demonstrate the action of root-pressure. (*a*) Glass jar containing water. (*b*) Thistle funnel containing a strong solution of sugar, closed by a firmly tied piece of wet bladder. The level of the solution will gradually rise in the tube of the funnel as it attracts the water. (*c*) Improvised wire support for the funnel. (*d*) Level of water.

We know now that plants require water, and substances dissolved therein that exist in the soil, in order to live. Is this all? What else does a plant get? The class may not readily respond to this, but it can be pointed out that green plants are not found in places absolutely deprived of light, though some are specially adapted to live in deep gloom. Presumably, then, light is necessary to them, just as water is. Further, we have not observed plants growing in places in which no air exists, if such places in a state of nature can be imagined, for air is ‘ dissolved in water,’ if we may make use of a generally accepted expression. Take some of the young wallflower plants growing in pots, leave some in the window and place others in a cupboard that can be closed to the exclusion of all light. At the end of a week examine and compare the two sets of plants. It will be found that those in the cupboard certainly have grown. But how ? They will call forth the exclamation that they are ‘ outgrowing their strength,’ and, indeed, this is precisely what has been happening. They have been growing, sacrificing part of their substance in order to attain length that may bring them into the light so that they may live a properly balanced existence. When we attempted to grow beans in distilled water we saw that the leaves became yellow and the plants languished and would have died had we not added certain salts to the water. When we added all the chemicals except the iron we found that while the plants grew to a certain extent they were, nevertheless, sickly, and did not possess that robust appearance and green colour that are characteristic of healthy plant life. If we think of ourselves, we know what is meant by an anæmic condition, for which iron is prescribed by medical men. The plants deprived of iron seemed similarly to be suffering, and did not make the rich green colour that may be compared to the condition we describe as possessing ‘ good red blood.’ What, then, is the function of this green stuff that, in view of its commonness, must be very important ?

---

[1] See p. 54.

We already know that it is called chlorophyll. Now plants that have not a green colour, *i.e.*, that do not contain chlorophyll, are generally parasitic—that is to say that, like men and women whom we describe as parasites on society, they do not live upon their own labour, but upon the labour of others. We may properly infer that the green matter is an important factor in the life of the plant, and that it assists it in getting its living. It is, in fact, a substance which absorbs the light of the sun, and, by means of the substances absorbed by the roots with the water, manufactures food. How can we prove this ? Unless we can prove it our conclusion rests on conjecture only ; it may be right or it may not be. Our rapidly growing bean plants would show us that this must be so—that plants do obtain part of their food from the air. The plant put to grow in the prepared solution rapidly attained a very much greater size and weight than it possessed before. We may weigh such a plant when we place it in the solution, wait until it has considerably increased in size, and then cut off enough of the mature plant to equal its weight originally. How can the extra part be accounted for ? The substance must have been derived from another source. Was it derived from the water ? We could test this, or people accustomed to the weighing of very minute quantities with great exactness could test it for us. We know what the chemicals we placed in the water weighed, so we might dry off the solution and have the dried sediment weighed. The result would show that the plant had consumed but a very tiny part of the substances in solution. Is the difference accounted for by water—is it water ? Clearly it is not all water, because if it were only water it would look either like water or like ice or steam, for water can only take these forms. We can evaporate the water, and then we have a dry plant, hard and brittle, that powders between the fingers. If we apply a light to it, it will burn—that is to say, it will combine with oxygen, and some of it will pass off in the form of gas.

What is the substance that burns ? It appears to be like charcoal. Most children know that " Charcoal, coal, and diamonds are all made of carbon," and they will readily understand that starch is also a substance that is ' made of ' carbon. A piece of starch can be treated with heat, and will behave very similarly to our dried plant under like treatment. Does the plant also contain carbon, and is this accountable for the extra weight ? The children can all carry out a little experiment by means of which they can satisfy themselves that starch is contained in the plant, that it is this that accounts for the extra weight ; that starch was not contained in the solution in which the plant was grown, and that the only other source from which it could have been acquired is the air. As atmospheric air consists of oxygen and nitrogen with a small admixture of carbonic acid gas, we shall probably be able to prove that the plant does feed upon the air.

If a piece of starch be treated with iodine it turns dark blue or, as chemists say, gives a blue reaction. Iodine should be applied to a piece of starch and this fact noted. The blue colour resulting therefrom is the test for starch, and whenever this reaction follows the application of iodine we know that starch is present. Exactly the same thing happens if we apply iodine to flour or to a piece of potato. Leaves may be picked from our wallflower plants—strong, healthy, green leaves, gathered in the afternoon when they have been exposed all the morning on the plant to good, strong sunlight. To facilitate their treatment they should be placed for a second or two in boiling water, which will make them flaccid, then soaked in methylated spirit until they are reduced to a white or pale yellow appearance, and finally washed well in water until they have lost any hardness they may have acquired in the methylated spirit. If then iodine be applied to them they will acquire the same deep blue-black tint as did the starch, the flour, and the potato chip. We are therefore justified in saying that the plant contains starch, and we know with a good deal of certainty whence it came. We have proved that it is there, and we have next to prove that it came from the air, which is, so far as we have proceeded at present, only an intelligent presumption.

Let each child cover up one of the leaves of his wallflower plant—one that is well exposed. This may be effected in many ways. The wallflower is not best suited for this experiment, but it will do. The leaf can be wrapped up in tinfoil, but any method that will shut out light will do, and the whole plant can then be exposed to strong sunlight for two days or more. In the afternoon one covered leaf and one uncovered leaf from each plant should be plucked and subjected to the test for starch outlined in the preceding paragraph. The leaves that have been covered up will not give the deep blue-black stain that is given by the leaves that have been exposed to the sunlight.

It seems necessary to go farther with this, because intelligent children who have been taught to think by the experiments they have carried out will not be satisfied that the starch comes from the air, although it may be admitted that carbon, of which starch is made, is contained in the air which bathes the growing plant. To carry this matter beyond doubt appears to require another experiment. Can we grow plants in air that has been deprived of its carbonic acid gas, and if we can will the plant continue to manufacture starch ? We can try to do so, but some rather elaborate apparatus is required, and this may not always be available ; it involves so many joints that there is danger of the experiment failing through the entrance of ordinary air. It is, however, desirable to introduce this experiment if possible. The apparatus required consists of a large bell jar capable of holding a growing plant, open at the base as well as the mouth, a plate in which it can stand, two ordinary jars the size of which is unimportant, glass tubing, large bungs capable of closing the jars, vaseline or paraffin wax, caustic potash, lime-water, a stand upon which to place the plant (a flat stone will suffice), and one of the young wallflower plants growing in a pot. Although we are carrying on our investigations with our wallflower, it is as well again to point out that for many of these experiments a quicker-growing plant is more desirable—a young bean plant would be in every way suitable. Make a solution of the caustic potash by dissolving about one and a half sticks in half a pint of water and half fill one of the small jars, closing the top with a cork. Place lime-water in another, similarly closing it. Then put lime-water (about two ounces of slaked lime will make one and a half or two pints) into the dish to the depth of, say, half an inch. Place the stand in it and the plant on the stand, and then cover the plant with the bell jar, the mouth of which must be in the lime-water so that no air can enter as a result of the inequalities of surface between the lip of the bell jar and the dish in which it is standing. The top of the bell jar can now be closed with a cork. All corks must fit completely, and sealing may be made more effective by filling the edges with vaseline, lard, or paraffin wax. In each of the corks of the jars containing the caustic potash and the lime-water two holes capable of taking the glass tubing must now be pierced. In one hole in the former insert a piece of glass tubing so that its end passes down into the liquid almost to the bottom of the jar. Then, by holding it in a gas flame, bend a longer piece of glass tubing so as to form three sides of a rectangular figure, one of the arms of which is longer than the other. With this the two small jars may be connected up, the short arm of the tube passing into the first jar, but not into the caustic potash solution, and the longer one into the second jar and right down into the lime-water. Now bend a similar but longer piece of tubing to enable one arm to be inserted into the jar holding lime-water, but not into the lime-water itself, and the other into the bell jar containing the plant, this also not entering the lime-water in the dish. Into the other hole in the cork of the bell jar insert a small, straight piece of glass tubing, on the end of which a piece of rubber tubing, with its end securely closed by means of a clip, should be inserted. If the apparatus has been correctly set up it will be clear that if the air is drawn through the rubber tube by suction, which may be applied by means of one's mouth, the air drawn into the bell jar will be such as has been drawn through the caustic potash and the lime-water; if the rubber tube is closed by pressure from the fingers and then doubled over and clamped by the clip

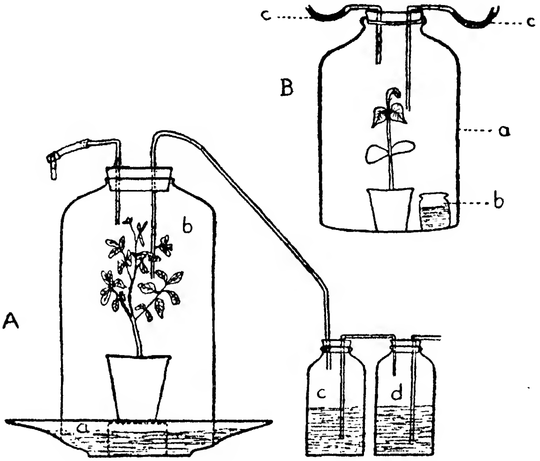


FIG. 9.—Experiments to demonstrate the effects of growing plants in air deprived of carbon dioxide. A. (*a*) Plate containing lime-water. (*b*) Jar securely closed at top. (*c*) Jar containing lime-water. (*d*) Jar containing solution of caustic potash. (For (*c*) and (*d*) ordinary pickle-jars are serviceable.) B. A simpler experiment generally effective with a quickly growing plant such as a young pea or bean. (*a*) A confectioner's jar. (*b*) Jar containing a solution of caustic potash. (*c*) Two bent tubes packed loosely where shown with pieces of caustic potash.

before the suction is removed, no air can be contained in the jar that has not so journeyed. In order that our experiment may have the desired result the holes in the corks through which the tubes have been inserted should be made air-tight by means of lard, paraffin wax, or vaseline, to ensure that no ordinary air enters by the otherwise inevitable leaks between the glass tubes and the corks. Each day the suction can be repeated, so that fresh air may be drawn into the bell jar.

The effects of so growing a plant will be apparent at an early date, and the quicker growing the plant the more noticeable will be the effects. Rapid growth will be slowed down, the leaves put forth will be small, and in a very short time the plant will die. If its leaves were tested for starch any time after the first day they would be found almost innocent of it, and would present under the iodine test a very different appearance from that of other leaves so treated. Yet the plant was supplied with air, and we assumed that the starch manufactured by plants was obtained from the carbon dioxide that exists with the oxygen in the air. What, then, have we demonstrated by our experiment? Just this, that in passing through the caustic potash solution and the lime-water the air was made to give up all its carbon, and that the air that entered the bell jar and surrounded the plant contained no carbon at all—and our plant died. In other respects the air was normal, and it should have sustained life, but the plant starved. We are beginning to see that, although we have regarded plants as rather listless things, they turn to their use foodstuffs of a very simple nature and build up strong bodies well fitted to their environment.

The principal constituents of atmospheric air are oxygen and nitrogen. The amount of carbon dioxide in the air is small. Carbon dioxide is formed of carbon and oxygen. We know that it must be breathed in by the plant, because we know that the plant makes use of the carbon. We can easily determine that it does not make the same full use of the oxygen, for it returns oxygen to the air. This may be most readily demonstrated by means of a water plant, which, though living in water, which consists mainly of oxygen and hydrogen but also contains carbonic acid, nevertheless feeds upon the same substances as do land plants. Every school should possess an aquarium—several, in fact—and an aquarium in which water plants are growing will indicate very clearly the return of the oxygen to the air. When the full sun is on the plants it will be noticed that bubbles form on the leaves, become detached, float upward, and discharge into the air. Some plants exhibit this phenomenon better than others, and none more strikingly than the Canadian water-weed (*Elodea*). The bubbles, or rather their contents, may be collected by inverting a glass funnel over a bunch of the plant and a test-tube over the funnel, the latter being placed in the water and put into position so that it contains no air. The bubbles will be collected by the funnel and directed into the test-tube, and as they rise they will accumulate in the dome formed by the inverted test-tube, slowly displacing water as they do so. When nearly all the water has been ejected the test-tube may be removed by raising it until the thumb can be applied to its mouth as a cork, when it may be moved above the surface of the water. If the thumb can be kept in position and a match struck we can show that the plant gives off oxygen. Use a common match, the stick of which will glow after the light is extinguished ; blow it out, and put the glowing part into the tube. If the necessary care has been taken the match-stick will burst into flame. This is known as the test for oxygen, or more correctly the test for pure oxygen. If oxygen is mixed with other things, as it is in the air, it will not cause a glowing stick to burst into flame ; but it will if it is present in a proportion much greater than it is in the air; the greater the proportion of oxygen the more fierce will be the combustion. The experiment has established the fact that the plant gives off oxygen. This it has absorbed from the water in the form of carbonic acid, which consists of carbon, hydrogen, and oxygen. It retains the carbon, storing it in the form of starch, and returns most of the oxygen to the water, whence the greater part of it is passed directly to the air. And what a water plant does in this respect a land plant also does, but it is easier to collect the

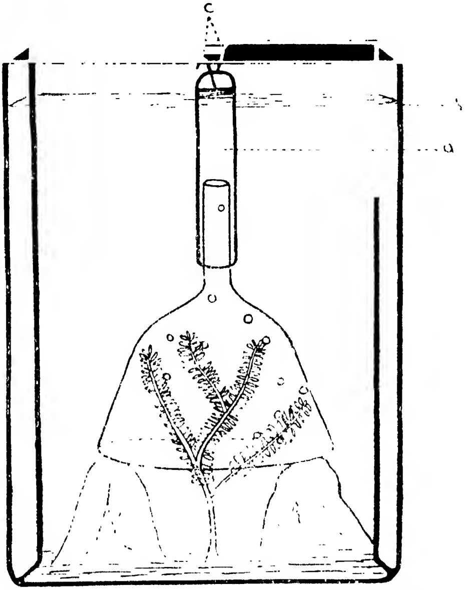


Fig. 10.—An experiment to show plants returning oxygen to the air. A funnel is placed over a plant growing in water in an aquarium in the sunshine, to control the bubbles of oxygen, which are collected in the inverted tube (*a*), displacing the water. (*b*) Level of water in aquarium. (*c*) Wire support for tube.

oxygen breathed out by a water plant than that breathed out by a land plant.

Plants breathe, as do animals. For children who have reached an age when they may grasp some of the elements of chemistry a fuller lesson on the respiration of plants may be planned. It is often urged that biology cannot be taught usefully until the elements of chemistry and physics have been apprehended, but the time is not far distant when all elementary work in biology, chemistry, and physics will be done in the same syllabus. Let us examine the question of the respiration of plants. The plants are surrounded by air consisting, mainly, of oxygen and nitrogen, about four parts of the latter to one of the former, and a seemingly infinitesimal portion (about ·04 per cent.) of carbon dioxide (CO_2), which consists of one part of carbon to two parts of oxygen. The association of the carbon and oxygen is very close as a rule, but when the CO_2 is absorbed in the leaf of a plant it takes up some of the water (H_2O) contained in the leaf and forms a different substance, carbonic acid (H_2CO_3); the carbon, hydrogen, and oxygen of the latter are acted upon by the chlorophyll in the sunlight and become regrouped to form sugar. This is effected by the rearrangement of six parts of carbonic acid, and may be represented in this way:

$$6(H_2CO_3) = H_{12}C_6O_{18} = C_6H_{12}O_6 + O_{12}$$

the sugar being represented by $C_6H_{12}O_6$, while O_{12} represents the twelve parts of oxygen which are not required in the manufacture of the sugar and are set free. A considerable amount of carbonic acid is broken up in the formation of sugar, as may be readily understood by those who have seen the amount of oxygen returned to the air by the plant in the experiment figured on p. 71. We have to follow the process one stage

IX.—HORSE CHESTNUT (*Aesculus hippocastanum*).

A handsome flowering tree, the blooms of which both by their smell and colour attract insects.

Photo: C. H. Royston.

farther, for when the sugar has been formed one part of the water (H_2O) is driven off, leaving the starch ($C_6H_{10}O_5$), which is the substance we have been seeking. For supplies of starch animals are dependent upon plants.

When animals breathe they take in oxygen, which combines with the carbon of which their bodies are largely composed and burns it. The flame of a fire, as we have already observed, is the result of the combination of oxygen with the carbon in the material that is burning. In the case of burning material the union of the oxygen and the carbon is so rapid as to produce heat and flame. In the case of the breathing of the higher animals—birds and mammals—the union is sufficiently rapid to produce warmth, but not flame, while in other animals, though it may produce in the body of the animal a temperature higher than that of its surroundings, it does not raise it sufficiently fot it to be noticeable. The same action takes place in the breathing of plants, though here the combination of oxygen and carbon is even slower. But in all the cases mentioned—the fire, the mammal or bird, the so-called cold-blooded animal, and the plant—food or fuel is taken in and used to stoke the fire, for work is being done and waste matter produced, and repairs must be effected. It is not so difficult to prove this in the case of the slow-breathing plant as might be supposed. Fires, animals, and plants in burning or breathing give off carbon dioxide. We can demonstrate this by a never-failing experiment. Some beans or peas should be soaked in water overnight and then be placed in a jam-jar, the mouth of which should then be tightly closed and kept in a warm temperature until the following day. A match may then be struck and slipped into the jar when the cork is removed. The light will be extinguished. Now we know that this would not happen if a lighted match were introduced into any ordinary jar, and we know that the condition most likely to produce such immediate extinction is the presence of carbon dioxide. Fortunately, we can make an easy test for the presence of this gas. We need only lime-water. If the jar containing the germinating beans is emptied, as though it contained water, into the vessel containing lime-water, the lime-water will become cloudy owing to the formation in it of calcium carbonate, which is produced by the union of lime and carbon dioxide. The same result may be obtained by breathing into the lime-water through a tube the end of which is introduced into the water, showing that the same gas is breathed out by ourselves and, of course, by other animals. It is not necessary to empty the beans into the lime-water—indeed, to do so would spoil the experiment ; the carbon dioxide is heavier than air, and will therefore pour into the vessel containing the lime-water almost as water itself would.

We see that plants in growing breathe out the same gas that animals breathe out, and we now need to show that they breathe in oxygen. It is a little more difficult to set up an experiment to show this, but it can be done, and presents no difficulty that cannot be overcome provided the effort is made. We might make use of our germinating beans and peas, but a handful of wheat will be better, because the individual seeds take up less room, and in consequence a greater mass can be crowded into the same space. The wheat should be soaked in water for about twenty-four hours and then wrapped in damp flannel until sprouting begins, when as much as it will hold should be placed in a thistle funnel, leaving the tube free. A solution of caustic potash, such as was used in the experiments figured on p. 68, should be placed in a shallow pan, and the thistle funnel may be closed at the top by a piece of glass held down by wax, lard, or vaseline. Then, by means of a support, which may be improvised if the ordinary form is not available, the thistle funnel can be held over the vessel of caustic potash so that the thin end of the tube is well below the surface of the solution.

Let us take stock of the position. No air can enter the thistle funnel, because the mouth is so closed as to prevent its entry there. The other end is submerged in the caustic potash, which cuts off entry there. But the funnel itself contains the sprouting wheat and air. We know that the air consists of nitrogen and oxygen and some carbon dioxide. We want to demonstrate that the growing wheat will utilize the oxygen, or some of it, and will breathe it in and give off carbon dioxide. If the experiment has been set up in a suitable temperature, such as that of a living-room, in a very few hours we shall find that some of the caustic potash solution has been drawn up into the

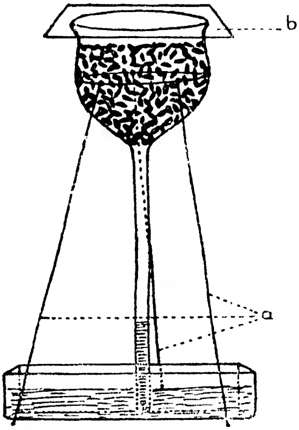


FIG. 11.—An experiment to demonstrate that growing plants breathe in oxygen. A thistle funnel containing sprouting wheat is suspended above a solution of caustic potash, which is drawn up into the tube of the funnel. (*a*) Improvised wire support. (*b*) Piece of glass closing the mouth of the funnel.

thin end of the funnel. Next day we shall find that the level of the solution in the tube has risen distinctly. Very little reasoning will enable us to decide what is taking place. Something has happened ; something has been removed to make room for the solution that has been drawn up into the tube ; some of the air must have been used up. The carbon dioxide in the air would, as we know, sink to the bottom of the tube and be absorbed by the caustic potash, but the total amount contained in the air in the funnel would not provide accommodation for the quantity of solution that has been drawn up. If we seek to show that it is the nitrogen that has disappeared we shall be unsuccessful, because there is no substance with which it is confluent—with which it could join. Is it, then, the oxygen that has been used up and has made room for the solution ? We already know that it can be so, because we have stated, but not so far proved, that oxygen is breathed in by the plant, and that it combines with the carbon of the living substance of the plant, which gives off carbon dioxide. This, we know, will sink to the bottom of the tube and be absorbed by the caustic potash, so making room for the solution to ascend in the tube. We have demonstrated that a plant does breathe in oxygen and give off carbon dioxide, as we do ourselves, and as all animals do, and we have also introduced a point at which our nature-study lesson might be diverted from the chemistry atmosphere in which it has been given to a physics atmosphere. But although the writer has felt bound to indicate the opportunities of teaching chemistry and physics through nature study, it must be left to a subsequent volume to explain in detail the lines upon which it may be carried out.

CHAPTER IV

A TYPICAL ANIMAL

IT was observed in the preceding chapter that a typical plant is one that would be generally recognized as a plant, and that although we might have chosen an oak-tree we could not properly regard it as typical, because it would not at first glance be regarded as a plant by everybody. Moreover, we could not have taken an oak-tree into the house, unless it it were a very young one, and have handled it so freely as we did the wallflower. Similarly, if we look round for a type from which to study animal life we should not choose Amœba, neither should we be wise in choosing an ostrich, though we appreciate the fact that both are types of animal life. For school purposes we cannot do better than select a rabbit, an animal that can be handled without any serious risk of injury to the person handling it, and which children can touch and fondle freely. Let it be noted to start with, however, that rabbits should not be lifted by their ears. The teacher must know how to handle his specimens, and in case he does not know how to handle a rabbit he will perhaps accept the advice that the most convenient way is to grasp the loose skin of its back in a full grip with one hand, merely taking the ears in the other or allowing the hind-legs to rest therein. A rabbit so lifted will remain perfectly still. There are obvious difficulties in the way of each child having a rabbit of its own to handle, but so far as possible each should be given the opportunity of examining one at close quarters.

There is really less to point out in a rabbit than in a plant, because motion seems to attract children, and they notice much more closely the characteristics of moving than of stationary things. It is not necessary, as it was in the case of the wall-flower, to point out that the rabbit breathes and eats, because it is common knowledge with children that in these respects it is not unlike ourselves, and rabbits are so often kept as pets that children frequently know a great deal about them. It is common experience, however, that the most striking thing about a rabbit, so far as children are concerned, is its ears, and to these a great deal too much importance is often ascribed. A class of quite small children seem to be oblivious of anything else, and it is often difficult to divert their attention to other points. We are told that the size of the ears is due to the fact that the rabbit is a defenceless creature, that it is dependent upon its power to detect sound easily and to seek its burrow as soon as it hears a premonitory or unfamiliar noise, and that the ears are so well developed as they are to collect the sounds and to give their owner early warning of danger. Provided we bear in mind that many animals with less developed ears are equally or more sensitive to sound than a rabbit is, there is no reason why this belief should not be fostered. Children readily apprehend that everything in existence has adapted itself to its surroundings so that it can defend itself, so far as is necessary to protect it, as a species, from extermination ; and that characteristics that do not tend to an animal's well-being lead to the death of the individual at an early age and so prevent it from having offspring, in which such characteristics would probably be perpetuated. Some animals are so big and strong and offensive that they require no means of defence—they are the lords of their country. They prey upon smaller and weaker animals, who would be exterminated were they provided with no protection. The means these have acquired are usually—but not always—great fecundity, as safeguarding the species, and speed and alertness, or such resemblance to their surroundings as will make them inconspicuous. Some possess both speed and protective resemblance, and the rabbit is an instance of this. Children should be encouraged to observe that rabbits never go far from their burrows, and that they are in colour extremely like their surroundings. The rabbit that is exhibited to a class will be the means of demonstrating this colour resemblance if one of a breed such as the Belgian hare, which is coloured similarly to the wild rabbit, can be procured for the purpose. Wild rabbits are most unsuitable for demonstration purposes because of the cruelty their capture and confinement involve. A tame rabbit left to its own devices in a class-room will jump about aimlessly, and it is not easy to demonstrate its capacity for speed ; but in any really rural district, so ubiquitous is he, it is not difficult to take children to the rabbit's haunts and to observe the rapidity with which he covers short distances and seeks his burrow.

It will be necessary to ensure that the class notices as many points as are visible, and we all see more of an object if we attempt to draw it. The outline will be easy. The covering should be noticed, the fine texture of the hair, and the finer character of the under pelt ; the long hind-limbs, by means of which locomotion is effected through vigorous leaps in which the short forelegs play little part, though they are strong in spite of their shortness and of great efficiency in excavating burrows ; the large eyes, which enable their owner to see behind and at the sides, and so to evade a closely pursuing enemy by well-timed leaps to right or left ; the hairs on the upper lip, tactile processes of great use in dark burrows where feeling takes the place of sight. These are immediately observable. In a wild rabbit the white under side of the tail should be pointed out. This is said to be a device to aid rabbits to escape an enemy. It is thought that when frightened rabbits dash for their burrows those farthest away see the white tails of the others and are enabled more readily to follow. To the writer this has always seemed a doubtful reason for the light-coloured tails. When a party of rabbits is alarmed some scamper off at once, but many rely upon their resemblance to their surroundings, and flatten themselves against the ground ; these may sometimes be almost trodden upon before they will move. That the white tails serve some useful purpose, however, is certain, or they would not persist. It is probable they are useful in the dim light of the burrow mouth.

In Chapter I we dealt with the characteristics of living organisms, and in Chapter III traced the functions through which they were expressed in a wallflower. We must now show the children that rabbits live, just as wallflowers live, and that while they feed and breathe and so forth various modifications of method exist to suit the conditions by which they are surrounded. Children know that rabbits eat—at least, most children do. Those who know can be asked to give their knowledge to the class. The wallflower, we found, obtained its food by absorbing from the soil and the air substances in a simple condition as they exist in nature before they have been worked up into complex forms. Now animals could not live very long were they simply to stick their feet into the earth and breathe vigorously in the sunlight, though such a life suits the wallflower remarkably well. Rabbits eat plants and the seeds of plants, and so, while they really live upon the same substances as do plants, they are unable, owing to their other activities, to feed so laboriously. The plants that have by feeding stored up reserves of food in various ways are eaten by animals, which thus make use of the work done by the plants to maintain their own lives. We see at a glance, therefore, that all living animals feed upon plants : carnivorous animals live upon herbivorous animals or animals that live upon herbivorous animals, and these have fed upon plants that have built themselves up from the simple chemical substances of the soil and air. Ultimately rabbits, lions, and ourselves are dependent upon these simple substances for food. This seems all very selfish and onesided to the frank mind of a child, whose sense of justice is clear and whose judgment is spontaneous, but, as we shall see later, it all forms part of the wonderful statement of account of Nature, and it all balances in the end, for animals, living and dead, return to the earth those substances upon which plants feed. The writer of " On Ilkla Moor bart 'at " would probably be content to be regarded as a humorist, but he really traced the great circle the circumference of which Nature travels.

The work the class has done in physiology, and the average age of the children, will determine how little or how much of the processes inside the body of the animal shall be taught in detail. It is clear that the subject of animal physiology is beyond the scope of these chapters, but enough should be taught in order that the scheme the writer has in view may be carried out—that is, to study the animal on the same lines as the wallflower. Probably in many cases we shall find that no physiology has been taught, and in these, to attain the object in view, the teacher will impart a very considerable amount of physiological instruction.

Digestion, it has frequently truly been said, begins in the mouth. It would not be desirable to attempt to examine the teeth of a living rabbit. The rabbit is easily injured, and it would resist any interference with its mouth. The jaws of a rabbit may be obtained without difficulty and can be minutely examined by the class. The front teeth (incisors) can be compared with our own. Their suitability for biting off pieces of food is apparent. Unlike ours, however, they are only partially covered with enamel, and at the backs the dentine is exposed. These teeth would, and do, wear away very quickly, and Nature has therefore made provision which was not necessary in our own case : the teeth grow as fast as they wear away—indeed, they would grow whether they were worn away or not. They are kept in order by the nature of the food eaten and by the gnawing habit which all rodents exhibit. For some distance the jaws are then toothless, until we come to the molars, which, like our own molars, triturate the food that has been bitten off by the incisors. The saliva, which mixes with the food during mastication, is not provided solely to keep the mouth moist ; it is an important element in digestion and at once gets to work on the food, and, owing to a special substance it possesses, called ptyalin, it converts by a chemical process the starch in the food into sugar, in which form it is more readily assimilable by the organs through which it passes. The saliva serves other purposes too : it dissolves at once some of the food and so enables it to be tasted, and it aids mastication. It is derived from three pairs of glands the existence of which is ordinarily unnoticed,

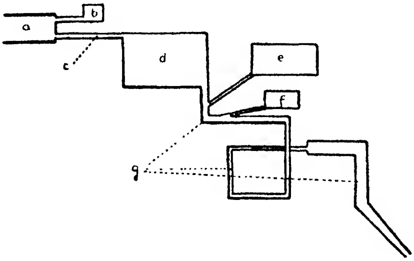


FIG. 12.—A diagrammatic representation of the digestive tract of a mammal, such as a rabbit. (*a*) Mouth. (*b*) Salivary glands, opening into mouth. (*c*) Gullet. (*d*) Stomach. (*e*) Liver, supplying bile to the intestine. (*f*) Pancreas, supplying pancreatic juice to the intestine. (*g*) The intestine, from which non-assimilable matter is eventually discharged.

but one pair becomes prominent when inflammation supervenes, producing in human beings the disease called mumps. Mastication grinds up the food and reduces it to a condition in which it can be dealt with in the stomach. Here it is churned up and, by the action of the secretions of glands in the wall of the stomach, reduced still further toward a condition in which it can be utilized. The stomach or gastric juices consist mainly of pepsin and hydrochloric acid, the pepsin having the effect of converting proteid, of which our most nutritious foods are composed, into peptone, in which condition proteid becomes soluble and is capable of being absorbed by the intestine, while the hydrochloric acid assists in this process and also acts as a controlling force against excessive fermentation. In due course the food is expelled from the stomach into the intestines. Very little of the food is absorbed by the stomach, but the intestine is so constructed as to absorb the soluble substances that have been produced in the process of digestion and to pass these substances into the lymph and the blood, when the whole organism becomes bathed by a nutritive fluid.

A simple account has been sketched. In detail the action is not quite so simple as this, and for the information of the teacher who may be desirous of going more fully into the matter, either to satisfy his own interest or because he desires to deal more completely with the physiological side with pupils who are old enough to appreciate it, it may for completeness be added that the final process of the conversion of food matter into nutritive matter takes place in the small intestine by the aid of the secretions of two glands, the liver and the pancreas. The liver secretes bile, which is poured into the intestine *via* the bile sac. It emulsifies fat, and, consequently, makes it more easy of absorption, and it retards putrefaction of the nutritive substances and waste. The pancreatic juice enters the intestine very close to the opening of the bile duct. It is of the greatest possible importance to the process of digestion and affects all types of food. It further emulsifies the fats, and amylopsin, one of its constituents, converts starch into sugar very much more effectively than does the ptyalin in saliva, while another constituent, trypsin, completes the conversion of proteid into peptone, which was commenced by the pepsin in the gastric juice.

Children who have followed the phenomenon of absorption of water and the substances dissolved therein by the roots of plants will experience no difficulty in appreciating that a surface so specially suited for the process as is the small intestine will absorb the soluble parts of food prepared by the processes just mentioned. The mucous membrane of the intestine is thrown into folds, to increase the absorptive surface, and further to increase it a vast number of villi are produced, almost like the projecting pieces of silk of which plush is made. The food substance, or the nutritive part of it, is now in a state of solution, and as it passes along the intestine, forced along by regular muscular contractions called peristaltic action, it is absorbed by the whole surface. The principal substances to be absorbed are fat, sugar, and peptones ; the fats are taken up by the processes of the lymph stream, called lacteals, while the sugar and peptones are absorbed by the capillaries of the blood stream.

The greater part of the nutritive matter is absorbed by the small intestine, after which the waste, indigestible material passes to the large intestine and is expelled from the body. This material has been likened to the clinker that would not burn and is cleared out from the furnace. The teacher will not fail to apply the simpler facts of digestion to teaching his class to observe the importance of a clean mouth, and the necessity for care of the teeth and proper mastication of food.

We come now to breathing. We discovered that the plant breathed, and ascertained what it took in and what it gave out. We do not need any elaborate experiments to show what the rabbit breathes, because we have already determined[1] the composition of atmospheric air, and we know that when the rabbit breathes in it draws into its lungs a quantity of air. The air passes directly into the lungs, which are two organs very light in substance lying in the fore-part of the body immediately behind the shoulders. The tubes that branch off from the windpipe to the lungs are known as the bronchi, and on entering the substance of the lungs each breaks up into a number of branches which in their turn divide and subdivide very similarly to the roots of a plant, the minute endings opening into air sacs. The air sacs are surrounded by the substance of the lung. Their walls, kept moist by the discharge of mucous glands, are coated with innumerable cilia or hair-like processes the movements of which sweep the mucus into the bronchi, where it is taken up and conveyed to the windpipe or trachea. The moist condition of the walls of the air sacs is of great importance, and in its absence breathing would be difficult, indeed impossible. Immediately beneath the mucous lining of the air sacs the tiny blood capillaries lie, ramifications from the pulmonary artery, and their contents, the blood, absorb the oxygen contained in the air, a process which we shall understand better when we have examined the composition of blood. There is an exchange of gases : the air gives to the blood oxygen, and receives back from the blood carbon dioxide and other waste products. We know that atmospheric air contains oxygen and nitrogen with a small amount of other gases, one of which is carbon dioxide. Carbon dioxide is contained among the gases given off by the combustion of non-living material. The teacher will not be slow to draw the well-known parallel between our bodies and steam-engines ; in both heat and energy are obtained by burning, the result of the combustion of the fuel with oxygen, while carbon dioxide and other wastes are given off in the process. But combustion in the animal body is, as we have observed, very slow, and is not rapid enough to produce a flame. It does, however, produce heat, as we all know, and when the rate of combustion is increased, as by exercise, greater heat is generated. The teacher should point out that carbon dioxide, a waste product of animal respiration, is breathed in by plants, which retain the carbon and convert it into starch, returning the oxygen to the air. The advantages accruing from the breathing of clean air may be suitably presented to a class, and the dangers that exist in the breathing of dirty air, *e.g.*, in a room with closed windows, may be pointed out. All the phenomena of living we are observing in the rabbit are common to ourselves.

---

[1] See Chapter III.

So much reference has been made to the blood that its consideration may no longer be delayed. The outward appearance of blood is familiar to most of us, and we know that any considerable loss of it seriously affects vitality and may menace life itself. One of the most interesting exhibits under the microscope is freshly drawn blood, and when a microscope is available the teacher should make every effort to ensure that each child examines a sample, which may be taken easily from one's finger end by a needle ; the finger and the needle must be clean, and the needle should be sterilized in a flame before being used. Blood will flow more readily if a string be wound round the base of the finger in a spiral manner toward the tip. It consists of three substances, plasma—the liquid part—the red corpuscles, and the white corpuscles, all of which may be clearly seen under the microscope. The red corpuscles are double-concave disks, pale in colour, so pale that their power unaided to give the blood its characteristic hue at once arouses astonishment and gives some indication of the vast numbers in which they exist in the plasma. When they are drawn from the body they tend to cluster together in ropes and suggest long piles of coins on a banker's counter thrown over on their edges. The white corpuscles, on the other hand, are colourless and of irregular shape, and perform amœboid movements—indeed, they resemble amœbæ. The red corpuscles contain a substance—hæmoglobin—that is as characteristic of red-blooded animals as chlorophyll is of green plants, and the relation of this to oxygen may be compared loosely with that of chlorophyll to carbon dioxide, for the oxygen in the air that is breathed in by the lungs combines with the hæmoglobin in the red corpuscles. The white corpuscles, or leucocytes, are considerably fewer in number than the red. They are the scavengers of the blood, and are found in greatest quantity in close proximity to wounds, where, it is thought, they engage in warfare with the bacteria of sepsis, being themselves destroyed in great numbers ; their dead bodies are found abundantly in the pus drawn from injuries to the body.

The point from which the blood system should be studied is the heart, and as the rabbit's vascular system is practically identical with that of the human body the teacher is advised thoroughly to grasp the details of the heart's action and of the system by which the blood is conveyed to and from the heart. The heart has frequently been described as a strong box built of muscles that are specially suited for contraction. The different organs in a living body are built up of tissue composed of cells that are in the nature of specialists. We saw that Amœba consists of only one cell, that that cell performs various functions such as locomotion and nutrition, and that when it wants to reproduce itself it divides. In a primitive state man was content with a kind of existence that knew nothing of the advantages (or, it may be added, the disadvantages) of specialization. He caught and cooked his own food, manufactured the weapons with which to catch it, and made his own clothing, boots, home, and bed. As he developed the power to organize he learned to appreciate the advantages that might result from specialization, and the production of food was left to those who were specially fitted or more inclined to procure it and who became more proficient owing to their being employed solely or mainly in such duties. Others of the community produced clothing and, presumably, homes. As we advance upward along the line of animal life from the single-celled protozoon, such as Amœba, we find some parts of the individual, or in some cases certain members of a colony, being set apart for special duties for which they are peculiarly suited, and for which they would, by use, become more suited. So we find muscle cells developing special ability to contract, cells building themselves into the skeleton or producing substances which form the skeleton, nerve cells acquiring special sensitiveness, other cells a capacity to absorb nutriment, and yet others the sole function of which is to ensure the continuance of their kind by propagating the species as widely as possible. The mammalian heart is built up of muscle—muscle in which power to contract is specially marked. It consists of four chambers—two auricles and two ventricles—and lies between the two lungs in the breast or thorax. The blood that has circulated through the body is received into the right auricle, which passes it into the right ventricle. The auricle may be regarded merely as a receptacle, but the ventricle, on receiving the blood—impure blood, it must be remembered, for it has travelled a vast distance and given up its oxygen—contracts and drives the blood along to the lungs. We have already satisfied ourselves as to what happens to it there; we saw that it absorbed oxygen and acquired its bright hue, the colour, as we say, of arterial blood. From the lungs it travels back to the heart, but to the left auricle, not to the right as before, and thence to the left ventricle, the contraction of which forces it out into the body stream, where it fulfils its function by carrying the oxygen it contains to all parts of the body and by absorbing in the intestines the products of digestion that feed all the cells in the body as they are carried to them. The large vessel that conveys the blood from the left ventricle and the vessels into which that vessel divides are known as arteries, and the arteries themselves give rise to a number of tiny tubes, known as capillaries, that ramify through every part of the body, and unite again and form veins, by means of which the blood is transported back to the right auricle of the heart. This is, as it were, a diagrammatic view of the matter; the actual manner in which it is effected is ingenious and worth study. Why does

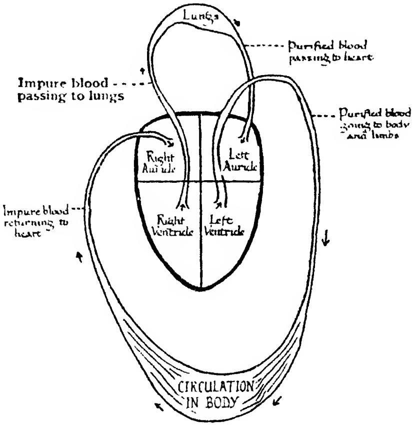

Lungs
Purified blood passing to heart
Impure blood passing to lungs
Purified blood going to body and limbs
Right Auricle
Left Auricle
Impure blood returning to heart
Right Ventricle
Left Ventricle
CIRCULATION IN BODY

FIG. 13.—A simple diagram showing the heart and the circulation of blood in a mammal.

the blood stream move as it does ? Why does it flow in a particular direction, and not flow back as a result of changed positions of the body—in fact, why does it not conform to the law of gravity in so far as it is free so to do ? But we do not say that water flowing up a pipe, drawn by a pump, or standing in a bottle on a table, is disobeying the law. The force exercised by the muscular contraction of the ventricles drives the blood into the arteries, and it cannot flow back because immediately it is ejected from the ventricles its pressure closes valves, the resistance of which is strengthened by the pressure of the blood. Why does it not flow back into the auricle, whence it came, when the ventricles contract ? For the same reason. Valves, that allow it readily to flow in one direction, effectually close and prohibit its passage back again. The valves between the auricles and the ventricles are known as auriculo-ventricular valves, for obvious reasons. Their name need not be remembered, or taught to children, but the teacher will as a matter of fact experience difficulty in forgetting them, even should he wish to, if he appreciates their position and function. They consist of five flaps or folds, three on the right side and two on the left. The valves that prevent the blood running back into the ventricle when it has been forced into the artery consist of six flaps, three on each side, and since they form little pockets shaped like half-moons they are known as semilunar valves.

When the ventricles have closed, driving the blood to the lungs on the one hand and into the general circulation of the body on the other, and the semilunar valves have closed, the movement of the blood is effected as a result of the elasticity of the arterial walls. The passage of the blood through the arteries may be likened to the passage of water through a rubber tube. If the water is forced through faster than the ordinary diameter of the tube permits, the rubber expands. If we attached a football bladder filled with water to the tube, and forced the water along by a series of regular compressions on the bladder, we should see quite clearly what happens as the blood is pumped by the regular contractions of the ventricle of the heart. As the arteries swell and recoil with the rhythmic beats, they provide a ‘ pulse ’ wherever an artery comes sufficiently near the surface of the body to be felt. We generally locate the pulse in the wrists of our own bodies, but a pulse may be felt, and even seen, wherever an artery approaches the skin. As, however, a wounded artery is a threat to life, all living species have tended to develop deep-seated arteries. Since like tends to produce like, and individuals with surface, and therefore vulnerable, arteries are specially liable to fatal accidents before they acquire ability to produce their kind, we can readily understand how it is that arteries are usually deep-seated.

We have considered how the blood percolates into all living tissues, and noticed its work of nutrition. We need not go into details concerning the double supply the liver obtains, or the work of the spleen ; there are numerous suitable works on animal physiology that will be consulted by those who are specially interested in the physiological side and who wish to develop it, but the class will probably take this in a course on human physiology. We must, however, complete our survey of the blood stream. We have considered the bathing of every organ in that stream by a system of capillaries into which the arteries divide. Now we have to observe that the blood which has been conducted through the organs by means of the capillaries is conveyed back to the heart by their union into veins. It will readily be grasped that the stream has lost much of its impetus at this stage. Still, it is being forced by pressure from behind. This pressure, however, is gentle and continuous and no longer pulsates. The veins, too, are unsuited for passing on the blood as the arteries pass it on. Their walls are thin and much less elastic, and were there no special provision the blood in a limb would collect until the walls of the vein became distended to bursting-point. The stream is maintained by the valves in the veins, which, as the pressure increases, open out and prevent the blood from falling back. The movement of the blood toward the heart is immensely assisted by ordinary muscular movement and by the act of breathing, which, alternately contracting and relaxing the walls of the veins, helps the blood forward.

It has been stated above that the capillaries of the blood system ramify through every organ, and bathe it in the life stream. As a general statement it is true. But the lymphatic system, which must be regarded as part of the blood system, is very important, and cannot be ignored. We have stated that every organ of the rabbit's body is built up of cells, and we know that each cell must be nourished and must breathe, or it will die. As a matter of fact the blood itself does not reach the individual cells, except so far as the blood-vessels are themselves composed of cells. The walls of the capillaries of the blood system are very thin, and allow part of the substance of the blood to ooze through them. The part that so escapes from the vessels is called lymph, which has been described as blood without red corpuscles, diluted with water. It arises and behaves as follows. On passing through the capillary walls it collects in irregular and ill-defined cavities in the tissues, out of which lymph capillaries open. Indeed, the lymphatic system forms a network of capillaries similar to that formed by the blood capillaries, in which the lymph, after escaping from the blood and bathing the tissues, collects. These capillaries pass into lymphatic glands and return the lymph to the blood stream by openings into veins. The movement of the lymph is also effected by muscular pressure, and every motion of the body, by contracting muscles and exerting pressure, effects movement of the lymph. The importance of the lymph cannot be overrated. It is the go-between for the blood and the tissues, the blood giving oxygen and food to the lymph, which passes these on to, say, a muscle cell, and receives in return carbonic acid and other wastes, which it passes on to the blood, whence they are excreted by the lungs and kidneys.

It is obvious that when presenting the facts of the circulatory system before a class the teacher is afforded opportunity of enlarging the subject and of applying it to the human body. The treatment of injuries can be discussed, and the differences between venous and arterial blood emphasized.

We come now to the muscular and skeletal parts of the rabbit's anatomy. The children can feel the flesh of a rabbit's hind-legs. What we generally call ' flesh ' is really muscle, and muscle, as we have seen, is composed of cells which have developed very highly the capacity to contract. The mere contraction of muscle would produce but little result in itself—so far as we can see, though we know now that it does assist the movements of the circulatory system. But in conjunction with the bones of the body the muscles produce a series of movements without which the rabbit could not live. The skeleton serves the purpose of a framework in and upon which the organs of the body live, and to which they are attached almost as the parts of a reinforced-concrete building are attached to the steel frame—with this difference, however: the muscles and the skeleton are destined to move to a much greater extent. Indeed, the muscles are designed themselves to move, and, in their movement, to transport the whole body. It is to be regretted that a piece of elastic does not act as a muscle does, because in many respects its action provides a ready means of demonstrating the effect of muscle in the movement of a limb. Care must be taken in explaining the difference: the elastic, in its action, effects movements that are very similar to those effected by the muscles, but its own action is different. If a jointed stick such as the leg of a folding camera-tripod be taken, and a piece of elastic be bound tightly to the top end of the middle joint, by stretching the elastic and fastening the other end to the top end of the top joint, we shall have a working model of the bottom and middle joints of the rabbit's hind-legs. When the elastic is stretched by pulling the two joints of the tripod into line we have a representation—of a kind—of the two joints of the limb when the extensor muscles are extended. When the elastic contracts it increases its girth, but diminishes its length, and in so doing draws up the middle joint of the tripod so that it tends to lie alongside the top joint. Children can demonstrate the action on their own arms. When the arm is extended the muscle is elongated, but when the bones of the lower arm are drawn up toward the bone of the upper arm the muscle—the famous biceps—shortens and swells out in the manner which is so much admired by the pugilistically inclined. The difference between the muscle and the elastic is this: the elastic is in a

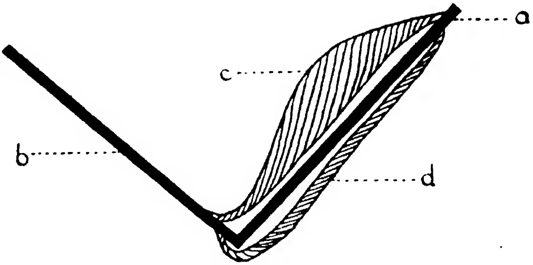


FIG. 14.—A diagrammatic representation of (*a*) the upper and (*b*) the lower bones of a limb. (*c*) The flexor muscle contracting and bending the limb. (*d*) The extensor muscle relaxed. The limb is straightened when the extensor muscle contracts and the flexor muscle relaxes.

state of rest when it has contracted, but the human biceps muscle is in a state of rest when it is nearly extended. In the case of the rabbit's hind-leg the position of rest is somewhat different, but this cannot be discussed at sufficient length ; the fact is, however, that muscle is in most cases normally somewhat stretched, as is evidenced by the effect on a broken bone, where the muscles, no longer attached to rigid supports, cause the broken ends of the bone to override one another ; in a state of complete rest, to which the muscles tend to move when the body is completely relaxed, the limbs and body assume a position that is characteristic for each particular kind of organism, and all movement involves the contraction of muscle. The heart is a huge muscle, comparatively, and it is very hard worked. It never gets such a rest as the muscles of the legs, for instance, get when the rabbit is not moving, so it takes its rest between the contractions, and rests for just about as long as it works.

When we fastened elastic to the camera-tripod we did something with the elastic very similar to what Nature has done with the muscles. The muscles would be of no use in themselves so far as moving the body is concerned. In a manner similar to that in which the elastic was attached to the tripod are the rabbit's muscles attached to the bones of its skeleton. Children will readily appreciate this. The teacher may demonstrate a great deal of the action between the muscles and the bones by means of a jointed stick, such as a tripod leg and a piece of elastic, and it is suggested that the movements of the human arm may be illustrated. We already have the biceps muscle in position, acting as a flexor muscle, *i.e.*, one that bends a limb ; by placing another piece of elastic at the back we can illustrate the action of the triceps muscle, an extensor muscle, *i.e.*, one that straightens the limb. Further, an elementary lesson on mechanics may be introduced, since all three types of lever may be demonstrated from the bones and muscles of the mammalian body. The imaginative teacher will already have perceived the facilities provided by nature study for instruction in both chemistry and physics.

The muscles to which we have referred so far have been skeletal muscles, but we noticed that the heart is a muscle. Many muscles are not associated with bones, though, nevertheless, they effect movement. Digestion is carried on by the help of the contraction of muscle fibre in the alimentary canal. The muscles that move at the will of the animal are composed of voluntary muscle fibre, while the heart and such other organs that move without any conscious volition on the part of their owner are composed of involuntary muscle fibre and are, as we shall see, controlled by a special system of nerves.

Having examined so much of the rabbit's body, and discovered that so much of what composes it performs functions that are also carried out, though differently, by plants, we find ourselves wondering how the various processes are co-ordinated. It is obvious that in the rabbit we have something very different from the plant ; we have an organism that is, in fact, living more actively than a plant and capable of carrying out movements that plants do not as a rule attempt. How is it that a rabbit can disport itself as it does ? A wallflower plant turns its leaves so that they may offer the greatest possible surface to the sun, but it has no power to move across the garden to another spot where the sunshine is more continuous or the soil richer. The rabbit possesses wonderful sense organs, and, so far, nothing similar has been detected in plants. These organs we call ' nerves,' and it is curious that although it is only by means of nerves that we know anything at all, yet we know less about the action of the nervous system than about any other system of the mammalian body. The nervous system consists of the brain, the spinal cord, and the nerves, and has been likened to a telegraph system. From the brain the long spinal cord stretches the whole length of the body of the rabbit, protected by the backbone, which consists of a number of separate bones called vertebræ. Every teacher has had the opportunity of observing the movements of the vertebral column of a mammal, and we need now only observe that the nerves are processes from the spinal cord which pass out through notches in the vertebræ, the latter serving the additional purpose of protecting the nerves from being pinched between the separate bones when the body is bent, which would inevitably happen except for this protection. The nerve-endings ramify to the surfaces of the body—to any organ, indeed, that is connected with a sense—and to the heart and the digestive organs.

How does it all work ? We do not know. Certain facts, however, have been established, and may be profitably introduced into a nature-study lesson. The brain consists of an outer covering of grey substance and an inner part of white matter ; the former is responsible for sensation, and it is there that the sensation of touch is received. The white matter connects the grey matter with the rest of the body by means of the spinal cord and nerves. The spinal cord consists of a centre of grey matter embedded in white substance, and it is from the grey matter that the nerves of the body have their origin. The nerves have each two roots in the spinal cord, one a dorsal or sensory root, the other a ventral or motor root. The two roots soon unite, however, and then divide up into branches, the ends of which become so numerous and small as to reach every individual muscle fibre in the body. The rabbit's acquaintance with all that goes on in the world around, all that goes on even in its own body, is due to the nerves, which bring the messages to the brain—all that it sees, hears, tastes, smells, and feels. All the living processes of its body, its movements and activities of every kind, are performed in consequence of messages flashed out from the brain in response to those stimuli set up by the impressions conveyed to the brain by the sensory nerve cells, which travel along the motor cells and instruct muscles to contract and glands to increase or diminish their activities. Each nerve consists of both sensory and motor fibres bound together, but having their origins in the dorsal and ventral roots respectively. We have not space in which to discuss reflex action, which takes place without the intervention of the will, and, indeed, independently of the brain, as we can prove by experiment. Neither can we examine the sympathetic nervous system, which sends nerve fibres along to internal organs such as the heart and other blood-vessels and those connected with digestion ; yet it is important to know that this special system provides nerve-endings in those organs, which pass on information as to their condition and needs to the little nodules or ganglia that connect up with some of the nerves leaving the spinal cord. The nerve-endings in the stomach, for instance, flash back the news when food arrives there, and the response comes in a message to the appropriate blood-vessels, which enlarge with an increased flow of blood and provide the glands of the stomach with material for the production of gastric juices necessary to deal with that food.

CHAPTER V

SEEDS AND EGGS

THE methods adopted by plants and animals for ensuring the continuation of their kind are numerous. We have observed in Chapter II that some animals multiply by dividing themselves into two or more pieces, their structure being so simple that division presents no difficulty to the inclusion in each of the resultant parts of all that is essential to the building up of a complete organism. Similar processes may be carried out by plants, since it is common experience that shoots may be taken which, if planted in suitable soil, will ‘ strike ’—that is, develop roots and begin independent existences. We may instance the geranium and the chrysanthemum, which are commonly propagated in this manner, and the willow and its kind, which are so tenacious of life that branches and twigs put into the ground to form a fence invariably develop roots and burst forth as new trees unless they are deliberately killed to prevent this. But this practice is not universal, and even the plants referred to do not rely on such methods, but upon the production of seeds, to ensure that when their life is over their progeny will continue on the earth.

Both seeds and eggs are common objects, easily obtainable, and familiar in appearance to every child. In our examination of seeds it would be desirable to deal with the seeds of the wallflower, which is now assumed to be familiar to the children who are receiving a course of instruction based upon these chapters. Unfortunately that plant, while so suitable in many respects for our purpose, produces rather small seeds, from which it would be difficult for children to learn anything. We need a big seed, and the seeds that suggest themselves are those of beans and peas, which can be obtained for little or nothing. Any beans or peas will answer our requirements, and the simplest solution of the question of their source would be for the teacher to go to a grocer's and buy a packet of dried peas. These are the seeds of some variety of cultivated culinary pea, and are in the condition in which Nature presents them to us except that they are sometimes treated with chemicals in order that they may have ' a good colour ' when they are boiled for the table. So far as the writer's experience goes, they are as fertile as the finest peas bought from a seedsman, and on the one occasion upon which he planted a row he found them quite as prolific as named varieties obtained in the orthodox manner. One such pea is comparable to a fertile egg, such as may be obtained from a dairyman. But because in raising crops or poultry we cannot afford to take risks we usually, but not always, as has been stated above, buy our seeds from a reputable seedsman and our eggs for hatching from a breeder who supplies eggs for this purpose, guarantees a certain proportion of fertile ones—and charges extra for his trouble and guarantee. The writer, however, as an experiment, once bought seven ' new-laid ' eggs from a milk-shop and placed them under a broody hen, with the result that he raised four chickens (two of them cockerels) ; a fifth was fertile, but was broken by the hen, and the two others were unfertile or stale. The point to observe is that a fertile seed is like a fertile egg in that it contains an embryo and a store of nutriment, and that both will, given the requisite conditions, develop into organisms like those from which they had their origin.

The class should be encouraged to give careful attention to the peas. They are quite dry, and apparently dead. But we know they are not dead, because it is common experience that desiccated seeds grow when they are encouraged so to do. Let the peas—sufficient to be handed round—be soaked in water the night preceding the lesson, because they will swell up, and assume the shape they possessed before they became separated from their parents and which they must assume before they can begin the journey through life. If we dry the surface of a pea after it has soaked in and absorbed water during the night, and then press it gently, we shall find that water is expelled from the seed coat, or testa. Where does this water come from? It must come from the inside of the seed coat. How does it come, since the coat is not damaged? We may experience difficulty in determining this question. But removal of the pressure of the fingers will cause air to be drawn in to replace the water expelled, and on again applying pressure water and air in the form of bubbles will be expelled, and we shall probably be able to distinguish a tiny hole in the seed coat. This hole is known as the micropyle, and it exists to enable moisture to be admitted more readily into the interior of the seed. Having established this, we may allow the coat to be gently taken off the seed, observing that it is protective and is no part of the seed proper, and that it bears a light mark denoting the point at which it was attached to the fruit before it separated from its fellows to start life on its own account. We shall now find that we have in our hands a pea looking at first glance not very different from what we had before we divested it of its coat, but it will soon be apparent that it now consists of two halves, joined in one place as with a hinge—indeed, we may prise the halves gently apart with a knife blade or even the nail tip, but in doing so we shall almost certainly cause the halves to part company. Since, however, we must separate them sooner or later this will not be regarded as a catastrophe, for until this happens we shall not see the young plant itself. On one half, neatly tucked away in the space that existed between the halves, we shall find a yellow bud, the first shoot, and we shall actually be able to distinguish the embryo leaves, while in the other direction will be found a white, pointed object which we can by experiment show is the embryo root or radicle. Apparently, then, we have in the bud and the root the complete young plant. If so, what purpose do the two fleshy, green substances serve ? The fact is that the yellow bud does not represent the whole of the visible foliage of the young plant, for the two green objects are the two first leaves or cotyledons, and it is from their axil that the bud proceeds. We know, therefore, that they are leaves, because the bud has its origin in their axil—a feature of all buds and shoots, as previously mentioned.

Why are these two leaves so different from other leaves ? Firstly, they protect the delicate bud and fragile root ; secondly, and this is very important, they serve as a source of nourishment for the embryo plant, which is not yet securing its sustenance from the air and the soil—indeed, we know that it is not in a position to do this, since its root is not in the soil neither are its green leaves exposed to sunlight and capable of making use of the carbon in the atmosphere. The young plant has to grow for some little time before it can make use either of its root or its green leaves. So, while these organs are growing, the little baby plant draws its nourishment from the cotyledons, which shrink and wither as the shoot and the root grow. We know [1] that a green plant makes starch from the carbon in the air and stores it for future consumption, and some of it goes to the ovary [2] of the plant in order that the ovules may have enough to see them through this stage. If uninjured peas are placed in a suitable environment the root will extend, pass through the micropyle, burst the seed coat, and grow downward toward water, so to ensure, in the first place, the water-supply to the plant while the shoot grows upward. Leaves always grow toward the sun and roots toward water, downward.

---

[1] See Chapter III.

[2] See Chapter VI.

Although the object of this chapter is to describe the seeds and eggs from which plants and animals develop, it seems desirable to indicate the lines along which children may be directed to experiment on seeds. It may be demonstrated that moisture, warmth, and air are necessary to the growth of seeds, and peas may be grown in different ways to this end. If the moistened peas be placed on a dry plate they will dry up again. If they are placed on damp moss the root will make its appearance and will quickly develop fine hairs, and, later, side shoots which we know are the rootlets. Growth will be arrested by cold and encouraged by warmth, but care must be taken that the growing peas do not come into contact with heat that will desiccate them. We shall find that growth is prematurely stopped unless the root has access to soil and the leaves to sunlight, and by marking the roots of peas growing in water we can show that it is the point of a root which grows, and not the root as a whole. We can also show the tendency of roots to grow downward by taking a young plant the root of which has been growing straight down and placing it horizontally on soil in a damp atmosphere, when the root point will grow down into the soil, forming a right angle with its original growth. It can further be shown that leaves grow toward the light by placing a straight-stemmed pea plant in a light-proof box or bag in the side of which a hole is cut, and we shall see that the stem will bend toward the hole and grow out through it. But all this belongs rather to the physiology of the growing plant than to a lesson on seeds.

The class will experience some surprise that the examination of the seed showed, comparatively, so completely developed a plant. The original ovule, at the time of fertilization,[1] consists of a single cell, and, after the ovule and the substance of the pollen grain have thoroughly fused, this cell partakes of the substance of both the mother cell and the father cell. Desiccation and rest come to it at a time when development has not gone so far as to cause death, and at this stage the rest may be prolonged—not indefinitely, but often for a very long time. Seed should not be too young—that is to say, it must have ripened—neither should it be too old ; seed that is not given the opportunity of germinating at the proper time deteriorates, and as each year passes any particular sample of seed shows a smaller percentage of fertility.

---

[1] See Chapter VI.

Seeds assume many remarkable shapes. Some are coloured and shaped protectively, and so escape falling prey to birds, insects, and other animals. Some, again, are enclosed in conspicuously coloured fruits, probably in order that animals may consume them and so transport them far from the parent plant, ensuring the widest possible distribution and the minimum overcrowding. But wonderful are the means adopted by different plants to ensure the dispersal of their seed, and a lesson of never-failing interest can be devised dealing with the subject. Seeds, when we divest them of their various integuments, are in essentials very much alike, notwithstanding differences in size and shape. They consist of the embryo plant, seed leaves or cotyledons, and an investing coat serving a protective purpose. In some cases this protective coat is very strong, in others brittle, in others soft and very easily damaged. Each plant has devised a covering for its seed which has proved suitable for its welfare during the period that elapses between the moment of separation and the time when, the radicle and bud having passed through the coat, protection is no longer necessary.

If the class has now grasped the general structure of a seed and the young plant by having drawn them in various conditions and stages, the teacher can proceed to the description of an egg. We know that the seed of a plant is a temporary house for the protection of a baby plant, which resulted from the fusion of a female cell with a male cell, a house stored with food to serve the purposes of the baby until it has adjusted its digestive organs—its root and leaves—so that they can secure nourishment for the little body. Now an egg is just the same kind of arrangement, but it grows into a young animal instead of into a young plant. If children know this in advance they will more readily apprehend the structures that are common to both seeds and eggs. We can hardly do better than take an ordinary hen's egg as our example, though the teacher will find that the instruction is much more effective if reference is made from time to time to other easily obtainable eggs, such as those of the snake, and frog, or toad. There are few children who do not know the general structure of a hen's egg ; all are familiar with the hard shell, the inner skin (there are really two), the ' white,' and the yolk. Most children have been told the half-truth that the yolk is there only to nourish the chicken before it leaves the egg, and the fiction that the chicken is made from the white. The yolk is the essential part of the egg ; it is the ovule, and it is invested by a delicate coat known as the vitelline membrane. Just as the ovules of a plant have their origin in an organ, the ovary, specially provided for their production, so the egg yolks have their origin in an organ, also called the ovary, in the body of the hen. Each yolk is fertilized in the body of the hen, before the white and the shell are deposited, by the pollen, or sperm, of a cockerel from anthers, or testes, after which the white and, later, the shell are placed round it as it passes along the channel by means of which it leaves the hen's body.

We are now in a position to compare the egg of the hen with the seed of the pea, and the relation between the shell of the former and the coat of the latter is immediately apparent. Both are protective. All eggs do not have hard shells, and for their difference in this respect a reason must be found. It is not a long way off, if we compare the difference in the treatment to which birds' eggs and, let us say, snakes' eggs are subjected. For twenty-one days the hen sits on her eggs to keep them warm, and from time to time during this period she moves them about so that the same eggs shall not always occupy the middle of the clutch, secure greater and more even warmth, and, consequently, hatch before the others. This movement can be more easily carried out with hard, spheroid objects than it could with soft-shelled bodies such as are the eggs of the snake. The weight of the hen's body rests on the eggs, and the hard shells sustain that weight. Snakes' eggs under similar pressure would be squeezed out of shape, and the formation of the young might be arrested and caused to take irregular courses. The eggs of the frog have even more delicate coverings, for the need even of a strong, parchment-like covering, such as the eggs of snakes possess, is not necessary for the protection of bodies that rest lightly in water and come into contact only with the equally soft, gelatinous coats of their fellows. Moreover, the shell is not an essential part of the egg as such, and it may therefore be the subject of such modifications as seem desirable to further the interests of the developing embryo.

If we break open a new-laid egg and empty the contents of the shell into a saucer we shall find that the skins to which reference has already been made are easily observable. They will adhere to the shell, and at first we shall notice only one. But if we examine the larger end of the shell we shall find that the skin does not adhere closely, and if we press it with the finger we shall meet with resistance, an indication that air exists between the skin and the shell. If the cavity be opened we shall find that this air sac is not surrounded by the skin on one side and the shell on the other, but by two skins, the existence of which is thereby demonstrated. Examining the contents of the saucer we shall see the yolk in a sea of white, and the tough, spiral processes that hold it at each end in its proper place in the white. What we shall not see, however, is the young chicken corresponding to the embryo of the plant, although the contents of the egg can be easily accepted as corresponding to the store of food, the cotyledons of the seed. Of course, our egg may be an unfertilized one, like the ovule of a plant that has not met with a pollen grain, but even if it is fertilized we shall see nothing to indicate the existence of an embryo chicken in the same stage of development as that of the embryo plant, though the blastoderm may be observed as a small pale spot, from which the development of the embryo proceeds.

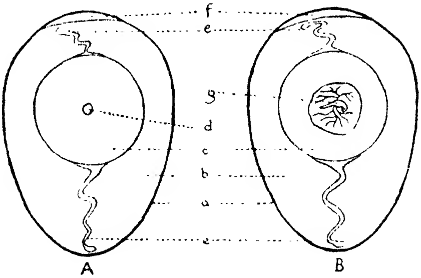


FIG. 15.—Somewhat diagrammatic representation of (A) a newly laid egg, and (B) an egg after two or three days' incubation. (*a*) Shell. (*b*) 'White.' (*c*) Yolk. (*d*) Blastoderm (in the case of a fertile egg the 'germ' or embryo). (*e*) Strands (chalazæ) at each end of the egg which anchor the yolk in position. (*f*) Air space. (*g*) Embryo chick and the blood-vessels taking part in its nutrition.

The germ cells of animals are generally exceedingly small, and it is only eggs that are crammed with food substances for the resulting young—such as those of birds, reptiles, fish, and insects—that can be studied without the use of a microscope. Unless the eggs are retained in the body of the mother for a considerable time after fertilization, there is nothing of the embryos to be seen at the time they are laid. But the teacher should not be deterred from showing children the developing embryo of an animal such as a bird, and since it is so easily obtainable it is strongly urged that older pupils be given the opportunity of seeing developing eggs, though it is probably not worth while in the case of quite young children, who cannot be expected to understand more than that the germ of life is implanted in the egg, which will develop into a bird amid suitable environment. If eggs that have been incubated for a day or two, at progressive intervals of a day or two, be broken open the embryo can be distinguished as readily as —indeed, more readily than—the embryo plant.

No useful purpose would be served by entering into the systematic study of embryology at this stage, but it may interest the teacher to know that by study of the growing embryo evidence of kinship of birds with reptiles and fish and many lower animals may be traced. It would, perhaps, be inadvisable while the matter is even yet a controversial one to dogmatize on the nature of this kinship. Needless to say, the development of the embryo of mammals, including the human species, opens up many interesting hypotheses.

Reference has been made to the fact that it is Nature's general practice to raise animals from eggs and plants from seeds. From their experience children will question this, because they know that baby cats and dogs come into the world in a fairly advanced state of development. But if reference be made to the life-history of guinea-pigs, for instance, it will be found that the young are brought into the world in an even more advanced state of development—able at once to run about. Equally big differences are observable among birds, though all come from hard-shelled eggs ; the young of the domestic fowl run about and pick up food a very short time after emergence from the egg, while others, such as the young of the song-thrush, are helpless for some time after being hatched, quite unable to stand, and, though able to open their mouths, incapable of picking up food, which has to be forced down into their crops by the beaks of the parent birds. The inference to be drawn is that birth in the case of different animals may take place at different periods of development, though it is commonly fixed for each species. The egg, then, while forming a stage in the life-history of most animals, does not always appear outside the body of the parent, and we have parallels among some plants, in which the seeds develop into young plants before being separated from their parents. Although very many animals, and it is nearly a universal rule until we come to mammals, produce eggs, which are incubated by the warmth of the body of the parent, or by heat of the sun, or by warmth resulting from decomposition of organic matter, others, such as most mammals, retain the eggs within their bodies. Development takes place there, and the babies are produced alive, sometimes at once capable of fending for themselves, sometimes able to run about, but dependent in most respects upon their parents, sometimes blind and helpless with much time before them until they can take any share in active life. Children should know that kittens have been growing for nine weeks within the body of their mother, who has been preparing for them throughout this period just as the mother and father birds prepared their nest prior to the laying of the eggs.

Enough has been said to indicate the conditions necessary to the development of both seeds and eggs. Warmth, clearly, is necessary, and moisture and air. Moisture and air are obtained in various ways. The unborn mammal breathes and draws nourishment from the blood stream of its parent, its circulatory system forming part of that of the mother, and the need for moisture also is there met. In the cases of animals developed from eggs such as the hen's and snake's the moisture is already contained in sufficient quantity in the egg itself, or is derived from the moist surroundings in which the egg is placed, while air is contained in the egg, fresh supplies being drawn through the porous shell.

Although the methods throughout the world of life are various the general principles are the same, and are based upon a great but mysterious scheme with the main lines of which children can be acquainted. If we succeed in helping them to grasp these lines, only the densest children will fail to appreciate their significance to themselves and their fellow-beings and, in time, man's origin and his place in the evolutionary system, the commencement of which we are beginning to understand, the end of which they may have a share in perfecting.

CHAPTER VI

MARRIAGE AMONG PLANTS

IN Chapter III, on the wallflower plant, passing reference only was made to its flowers, because it is necessary to devote special attention to these organs, which are so important that the rest of the plant may be said to consist of organs that wait upon the flowers and exist for no other purpose than that flowers may be produced. It is a matter of common knowledge that in all flowering plants a period of vegetative growth precedes the flowering period, and most of us are aware that even in the cases of coltsfoot (*Tussilago farfara*) and crocus, plants which are said to flower before the leaves appear, growth was proceeding throughout the previous summer. To children the flower is practically the plant; they often are conscious of no other part. This is not remarkable, because the object of the flower is to attract attention, though not the attention of human eyes. The flower of this plant, as of many others, is possessed of another striking quality besides that of colour—that of giving off a very pleasant odour hardly inferior either in quality or quantity to that given off by the violet. Both the colour and the odour exist for a purpose. We have explained to children that in nature everything has a purpose, or it would cease to exist. Of course, we cannot be quite certain what purpose is served by the colour and perfume of flowers, but because we know there is a purpose, and that insects visit flowers that possess those qualities, we assume, and probably rightly assume, that they exist in order to attract insects. We shall see later that the flower has a motive in attracting insects.

It has been stated that the wallflower may be found in bloom during a very great part of the year—indeed, in this respect it is surpassed by only one plant with which the author is acquainted, gorse. Certainly from February to October the teacher will experience no difficulty in obtaining blooms, even if they are not available in the school garden. We must furnish each child with one bloom, and direct his observation. Refusing to allow the more showy part to claim immediate attention, interest should be awakened in the flower stalk and the four green flower-leaves forming the calyx or cup in which the ' flower ' is set. At the moment we need not examine them further, but proceed to the attractive, brightly coloured inner floral-leaves, which are giving off the perfume and appear to constitute practically the whole of the flower. These four petals—there are always four in the wallflower—constitute the corolla or little crown that encircles the more important parts of the flower, which we shall soon examine. It may be advisable at this point to observe, for the information of the teacher if not for the pupils, that the possession of four petals indicates that the plant probably belongs to a group called Cruciferæ or cross-bearers, the name being suggested by the four petals corresponding to the points of a cross. The order Cruciferæ is a very large one, which includes a number of useful plants such as turnips and cabbages ; there are over fifty different species of the order found in this country, and about three times that number are known to exist and have been definitely declared as species. As a matter of fact systematic botanists, the very serious students who go thoroughly into the genealogy and relationship of plants, find a difficulty with the wallflower, because it does not possess a proper number of certain organs. We are more concerned with the organs themselves and their functions than with their origin, and with those organs as they

V. A SPRING SCENE—WILD HYACINTHS (*Hyacinthus nonscriptus*) AND YOUNG BRACKEN (*Pteridium aquilinum*)

Photo H. R. Royston

are now than with research into the question of whether they were always as they are now or whether they will in many thousands of years acquire different shapes or numbers. It should not be supposed, however, that such questions are unimportant ; the child who really ‘ takes ’ to botany is quite likely at a later date to find himself attracted to systematic botany, though he may retain a keen interest in plants without ever concerning himself about it.

So much for the more obvious parts of the bloom. Children who are not too young may begin a rough dissection by taking off the calyx, which we may now observe consists of the ‘ sepals,’ and two of the petals that go to make up the four-leaved corolla. They must be urged to great delicacy of action, and it is worth while explaining that they are destroying something they cannot put together again. The dissection is justified only because by performing it under capable direction they will learn things that will be useful knowledge and will enable them to some extent to understand how wonderfully built are plants ; that as in the end they are very much beyond our comprehension, flowers, like animals, should be treated with reverence and care. If the teacher wishes to carry out in practice the object the writer has in view, it is particularly important the children should be thoroughly impressed with the fact that they are dealing with the mysteries of living things, and with the instruments that Nature has devised in order that life may come, that it may be given the opportunities of fulfilling its functions before it is withdrawn, and that its chief function is the propagation of life itself.

After these operations have been performed it will be noticeable that the centre of the flower contains a number of stalks, each of which bears a loose head, and that in the middle is a longer, stouter stalk which clearly differs very considerably from those by which it is surrounded. It will be seen that the thinner stalks are six in number, and that while four are of the same length the remaining two are slightly longer, yet their heads are level with the heads of their companions, because their longer stalks have their origin lower down in the cup formed by the petals ; the two long ones differ from the others, moreover, in that they stand apart—they are on opposite sides of the flower. The six stalks with their heads are known as stamens, but the heads themselves have a special name ; they are called anthers, and are a very important part of the flower indeed. Further examination will indicate—the use of the pocket-lens is highly desirable—that the two longer stamens are fixed to the ' floor ' of the flower, and that the points at which they are fixed are deep green ; in fact, each appears to be fixed to a deep green tubercle. It is very important that these should be observed, because the tubercles are glands. We know that the purpose served by glands in the rabbit's body is to secrete substances necessary to the rabbit's well-being, and we should be misleading if we used the word in connexion with the

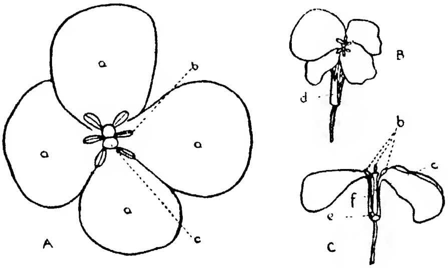


FIG. 16.—Inflorescence of a wallflower. A. View from above. (*a*) The four petals forming the corolla. (*b*) One of the six anthers. (*c*) The pistil, of which only the double stigma is seen. B. In addition to the organs shown in A are seen (*d*) the sepals forming the calyx. C. Partly dissected flower showing (*e*) a honey gland ; (*c*) the pistil ; (*f*) a stamen.

flower, when speaking to children, unless the glands also secreted a substance necessary to the plant's well-being. The glands at the bases of the long stamens are secreting nectar, or honey, and they are known as the honey glands.

Now let us examine the heads of the stamens. It is quite safe to assume that they are important, because they are complicated and clearly designed to fulfil a purpose. If we take some flowers that are ' ripe,' and hold them in a warm and dry atmosphere—in front of a fire, for instance—we shall observe that the stamen heads open along a well-marked groove. If we move the flowers into the cold, or sprinkle water on them, these heads will close ; we can watch the movement, so there is no doubt that it is real movement, just as the motions of the rabbit's mouth and nostrils are. If when the anthers are open we insert the point of a pin into the groove, we shall find on withdrawing it that the point is covered by a fine yellow dust, such as children must often have noticed on their own and their companions' noses after they have been smelling a lily. We can shake some of this yellow dust on to a piece of paper and examine it under the pocket-lens. We shall not thereby see very much more than we can see with the naked eye, but we shall see that it consists of minute particles that tend to adhere to one another. If a microscope is available we shall be able to distinguish the individual specks of which the golden dust is composed, and be amazed at the wonderful shape that has been worked out in so small a compass. The dust is called pollen, and it is very important, because without it no young wallflower would ever be produced to take the place of the old ones that die. We shall presently proceed further to deal with the function performed by the pollen, but we must now carefully examine the thick stalk in the middle of the flower, which is surrounded by the stamens.

This central organ is called the pistil. We might say that the pistil is the most important part of the flower, except for the fact that it would serve no purpose whatever were it not for the existence of the stamens. The stamens and the pistils of flowers stand in a similar relation to each other as do respectively capital and labour, male and female, rain and sunshine ; neither could function or be of any use in the world without the other, and of these, therefore, it is impossible to refer to the 'predominant partner.' The pistil we have already observed to be a larger organ than a stamen ; it is much stouter, especially toward its base, where it broadens out like an Indian club. The top part demands notice, because it is dark and velvety and is divided into two portions which together form what is known as the stigma. The lower, broad part of the pistil is called the ovary. On the whole, the pistil is not a very imposing object, but it is a very important one. If we are going to examine it, however, great care and the pocket-lens are required. Let us break the pistil off at its broad part, or cut it off with a sharp knife. As a matter of fact the pistil of some other plant is highly desirable, and if one with a large pistil can be obtained so much the better, because observation will be easier. Having broken it off press the sides gently, and some small bodies will be extruded. Children will probably say they look like eggs ; but if they say instead that they are seeds suggest that they look like little eggs. Well, that is what they are. They are eggs, in many respects the same as hens' eggs, which the children know are produced in the hen's body. And as a hen produces eggs from its body so does the plant produce eggs, or, as we call them, seeds, from its body. The name does not matter ; we might quite reasonably call hens' eggs seeds.

But it is most unlikely that the seeds, or ovules, as they are generally called—or, again, we might call them eggs—in the condition in which we have brought them out of the ovary would ever grow up into plants, because they lack something that the stamens exist to provide. The pistil is the mother of the young plants to be, and Nature always provides a father, even though the father comes into existence only at rare intervals in the history of a race of plants or animals. Among higher animals and some plants the father and mother consist of different individuals, but commonly among plants, and in many comparatively highly developed animals—such, for instance, as worms and snails—powers of both the father and mother are contained in one organism, and sometimes the same individual flower is so self-contained as to act both as father and mother to the plants of the next season.

Having inculcated the idea that the pistil is the mother part of the plant and the stamens the father part (with older pupils the teacher can make use of the expressions ' male organ ' and ' female organ '), the subject of fertilization may be proceeded with. Fertilization may be described as planting in the young eggs or ovules that which is necessary to stir them into action, so that they will grow, ripen, and ultimately, if planted amid suitable surroundings, grow up into organisms like that from which they were produced. Reference has been made to the honey glands at the bases of the two long stamens. If the children are required to examine the sepals of a complete flower of the wallflower plant they will observe that two of them are enlarged at their bases, and careful attention will show a direct connexion between the sacs that are formed by the two sepals and the honey glands ; in fact, the honey glands secrete the nectar or honey, which passes into the sacs at the bases of the sepals for storage purposes. The question at once arises, why is the honey formed and stored ? Strictly, the secretion is not honey ; it does not become honey until it has been elaborated by a bee. Children know that honey is obtained by bees from flowers, and they see the bees visiting the flowers. But it would be a mistake to suppose that the primary object of the secretion of nectar by the flower is that bees may come and convert it to their own uses, and a still greater one to suppose that it is in order that the bees may abstract and store it for our use. The wallflower blooms secrete nectar in order that bees may come and take it, but the coming and going of the bees is of direct and immense importance to the plants themselves.

We noticed that pollen was picked up by the pin point when we inserted it in one of the anthers, and we have recently observed that the anthers were the fathers of the plants that were to come into existence next season. We also observed that the work of the male part of the flower was to fertilize the ovules, in order that they might set to work and prepare themselves to be plants. The pollen is the power that stirs the ovules into action. Every ovule requires that it should be fertilized by a pollen grain. When children learn this they are amazed at the number of pollen grains that are produced compared with the number of ovules that have to be fertilized, but when we have explained to them how the work of fertilization is effected they will readily understand that Nature has devised the production of pollen on a large scale because of the vast number of pollen grains that are wasted. The chance that any individual pollen grain will find an ovule is very small, as we shall see. When the anthers open the pollen is extruded, and the wind would almost certainly blow some of it on to the stigma at the head of the pistil of the flower, and even possibly carry it to the stigmas of other wallflowers. Many seeds are so fertilized—by the wind, as we say. But although Nature permits such fertilization in the case of the wallflower, it has been argued that such methods of fertilization are not the most desirable, because they increase the probability that the pollen may fertilize the ovules of the same plant. The statements that Nature does not think this is the best way of doing it, that experience shows that when it is avoided the race of plants maintains its vigour, and that when it is not avoided the resulting plants tend to lose their vigour, will cause the older and more thoughtful pupils to realize that there is something behind our marriage laws, and to marvel that great revelations were vouchsafed to primitive peoples many thousands of years before we knew anything of the laws of genetics.

We are now in a position to explain the object with which the so-called honey is secreted by some plants. The bees come for the honey which the flower is storing for them and willingly gives up. It puts, however, just sufficient difficulty in the way of the visitor to cause it to spread itself over the stigma and anthers while it searches with its proboscis down into the floor of the flower to find the honey sacs at the bases of the sepals. We know what happened to the pin point. We can well imagine, and most school-children can see for themselves, what happens when a comparatively large animal such as a bee begins to push its hairy body and legs about among the anthers. The pollen is caught up in quantities, as the bee wishes it to be, because it wants pollen as well as honey with which to feed the young bees; but when it goes to the next wallflower it can hardly fail to leave some of its golden dust just where it is wanted, on the stigma of the pistil. As often as the pollen from one wallflower plant is deposited on a stigma of another the purpose for which the honey is secreted is fulfilled. The fact that the particular bee may not next visit a wallflower does not matter very much; if the pollen from a wallflower is brought to a different kind of flower nothing happens; but the pollen is carried in such quantities that although part is deposited on every flower the bee visits there is still some left when it does come to a wallflower. As a matter of fact, it is well known among those who habitually watch bees that they confine their visits to different individuals of the same kind of flower for quite a long time, and it is probable that bees find, as do human beings, that they can perform an action quicker and better if they confine themselves to that particular action. It may be that they become better acquainted with the anatomy of a particular species of flower the more often they visit it, and that they can exploit it more successfully.

Now that it has been observed how the pollen gets to the stigma, for what result may we look ? It was observed that the very tiny ovules that were extruded when we broke the pistil would not grow up to be young plants, because they had not been fertilized, and we know that the fertilization results from the pollen reaching the stigma of the flower. Close connexion with the stigma causes the pollen grains to become active, and each grain that is to fertilize an ovule sends out a tiny filament that grows down a channel that exists from the stigma to the ovary, and each filament unites with an ovule by a process which we described in Chapter V. The substance of a pollen grain actually enters into close association with the substance of an ovule ; each ovule that is so fertilized begins to grow, and, since the ovules are contained in the ovary, the ovary or pistil has to grow too. The process can be watched in flowering wallflowers that have been fertilized, and we can notice the growth that takes place day by day. The beautiful and odoriferous parts of the flower, having served their purpose, wither away, die, and fall off, and the pistil gradually assumes a long, pod-like shape. If we open it we shall find that it is now simply a seed-box, divided into two chambers. At this stage it is called a fruit. We regard fruit usually as some vegetable product that is good to eat and at the same time has an agreeable flavour, but in its botanical sense the word has an exact meaning, and can be applied only to one part of a plant—namely, the protecting case for the embryo plant, or, as we have described it, a seed-box.

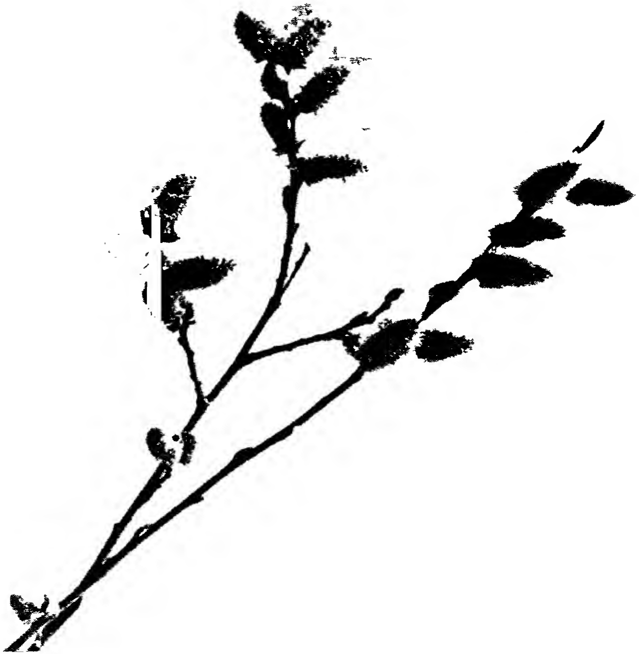
Various are the devices of plants to protect their seeds from harm, and the teacher may well point out that there is a parallel in the care shown by the parents of young animals to provide loving protection for their young, which they regard as their most precious possessions, and that it is merely an extension of the subject to consider the care that human parents bestow upon their children—at least, in all normal cases. Soon, however, the young plant eggs, consisting of ovules that have been fertilized by pollen grains, and are now entitled to be called seeds, reach a condition when, like children and other animals, they have to go forth into the world and make their own way in life. A time comes when they have grown as large as is desirable for their future good, and then the seed-box begins to dry up and in drying to contract under the influence of the sun, which evaporates the moisture faster than it is conveyed by the plant stem ; the rise of the sap to the fruit after it has nourished the seeds is gradually cut off by the changes that take place at its base. Having regard to the structure of the fruit and its stalk, it is not difficult to forecast what will happen as a result of desiccation and the stresses imposed by resultant contraction : the seed-box splits open along the middle of its long axis, and the two halves fly out to the right and the left respectively, while still remaining fixed at the top, assuming the appearance of an arrow-head. At this point we see the seeds still adhering to their papery bed, but obviously very loosely connected to it, and in due course they fall to the ground, where they find themselves in an environment in which they are enabled to begin an existence as independent plants. It is likely that in the act of opening the case the seeds will be scattered, and wonderful are the means that have been devised by some plants to disperse their seeds as far as possible from the parent plant. The seeds of the wallflower are discoid bodies, and their edges are furnished with a papery membrane that aids them to some extent to travel in their descent to the ground away from their place of origin, as may be illustrated if cardboard disks are thrown into the air, especially when a wind is blowing.

Lest the foregoing paragraph should lead to any confusion of terms, it seems well to explain (1) that seeds are ovules that have been fertilized by pollen grains, and that will grow into plants ; (2) that ovules are unfertilized, and will not, without fertilization, grow into plants ; (3) that ovules in plants correspond to unfertilized eggs of a hen ; (4) that seeds correspond to fertilized eggs of a hen.

In dealing with the question of reproduction the teacher may consider it desirable at the first lesson on the subject to ignore the honey or nectar glands and sacs, and to deal with reproduction exclusively by a study of self-fertilizing flowers. He will find he can speak more freely by so doing. The stamens and the pistils can then be referred to without difficulty as father organs and mother organs—indeed, the plant has been referred to as a house, and a ‘ perfect ’ flower, *i.e.*, one possessing both male and female organs, as the father and mother living together in one room thereof. This will appeal to children, and will set their minds on the right track from the start. It can subsequently be explained that Nature “ abhors self-fertilization.” Darwin has shown that, while self-fertilization by the anthers and pistil of the same flower or plant is permitted, and in some plants apparently forms the only method of fertilization—*e.g.*, the garden pea, in which the organs are ripe and the ovules fertilized before the flower opens—nevertheless, cross-fertilization (*i.e.*, of the pistil of one plant by the anthers of another) produces more robust plants and plants that reproduce themselves with greater certainty and are capable of better withstanding adverse conditions. Steps can next be taken to show that flowers have devised a means of avoiding marriage with close relations, and reference can then be made to the nectar glands and sacs, bright colours, and agreeable scents. The plant has, however, to make some effort and sacrifice to attain the greater good. Here again it is true that neither we nor any other created thing will ever attain desirable ends by sitting still and hoping for them. The energy of the plant that aims at cross-fertilization and a really desirable marriage must be in part expended in further modifying its flowers, in developing colours and odours, and in producing and storing honey—not, it must be observed, that its vanity may be appealed to by the attentions of eligible suitors, but that its offspring may have the best chances that can be given them by having had fathers most likely to provide them with robust constitutions. So these qualities are developed to attract bees and other animals, which act as the priest who unites the parents, and the fertilizing pollen is brought often from a considerable distance.

The next step appears to be to point out that in the case of some plants the fathers occupy flowers by themselves, though on the same plant. Children in rural districts are acquainted with the vegetable marrow plant, and should be advised to examine the two different kinds of flower that grow on each plant, the male (staminate) flower and the female (pistillate) flower. The difference is apparent. But some plants produce only male flowers, while other individuals of the same species produce only female flowers. These plants have been likened to houses in which only the fathers inhabit the rooms in one house, while only the mothers inhabit the rooms in another. As an illustration that commends itself as very suitable for school purposes we may choose the willow-tree, thereby seizing the opportunity of emphasizing the fact that trees, too, are plants, differing only in size from the smaller vegetable organisms. Moreover, the flowers of the willow are familiar to town and country children alike, because the willow branches bearing their 'catkins,' as they are generally called, are the well-known 'palms' of Passiontide—in medieval England they doubtless were the only 'palms' used in the ceremonies that precede the High Mass on Palm Sunday. But in choosing the flowers of the willow-tree the opportunity is afforded to explain that, although the willow is mainly dependent upon the wind for fertilization, the reproductive organs of plants are not flowers only when they are conspicuous to human eyes ; they may be very inconspicuous to our eyes, yet succeed in attracting insects and in carrying out all the functions of even so gorgeous a flower as the sunflower. Most people must have observed bees exploring the inconspicuous flower of the willow. Owing to the large number of varieties of willow and sallow that exist in this country the teacher may experience difficulty in ensuring that specimens from male and female trees of the same species have been secured. But the flowers of which the catkins are composed can readily be relegated to their proper sex, and it does not matter very much if we accidentally select a branch from a male tree of one species and one from a female tree of another, closely allied, species. The first thing that must be explained is that the tree from which the second catkin-bearing branch was secured is a mother tree.

The branches can be handed round and carefully examined by the class. The difference between their respective catkins



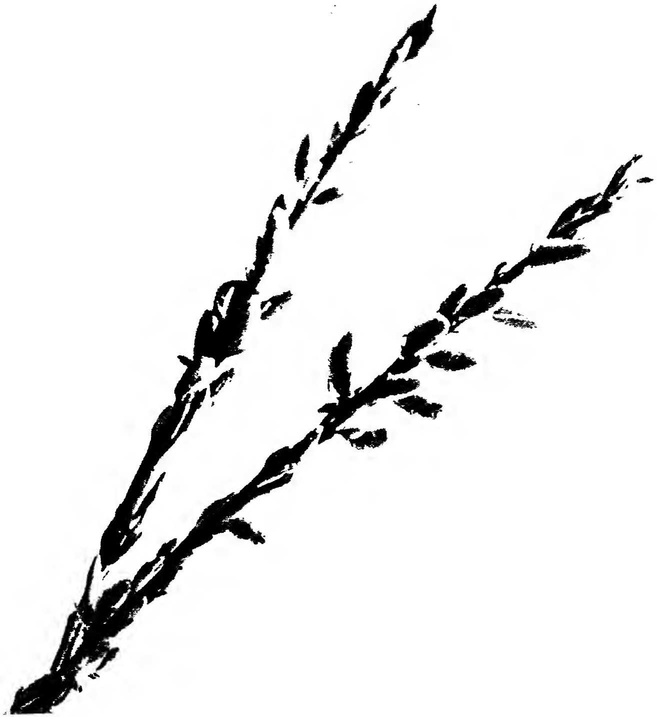
VI. THE FLOWERS OF A MALE WILLOW-TREE

Photo H. R. Royston

needs but little demonstration. As is so often the case in nature, the male is to our eyes the handsomer. The class may be asked to observe that this is almost the universal rule, the most familiar and easily verified examples of which are birds. The catkins owe their beauty to their mass formation, because if we examine the individual flowers of which they are composed we shall find them to be very modest productions as compared with our individual wallflower bloom. Let us examine the father catkins first: they may be easily distinguished merely because they are indubitably handsomer; they are shorter, but they are bushier, and more yellow and decorative, and softer in appearance. It may easily be seen that each male catkin consists of a large number of separate flowers, all more or less alike, but extremely simple—simple, that is to say, as compared with the ‘ flowers ’ which the word usually conjures up in our minds. Each flower consists of a modified leaf, or bract, in the axil of which are produced a pair of stamens bearing anthers. The flowers of which the female catkins are composed are not more elaborate. Here also each flower consists of a bract bearing in its axil an ovary with a double stigma. Since these organs always appear on different trees, it will be obvious that self-fertilization is impossible. The catkins are visited by bees and other insects, but depend in the main upon wind pollination. The fertilized ovary develops into a fruit, which opens in the early summer by division into two parts, exposing a large number of downy seeds, which are caught up by the wind and carried, maybe, enormous distances before they alight. And how many alight amid surroundings suitable for their future development and growth? Very few. The wastage is enormous, and it is met by the production of enormous quantities of seed. The extra work imposed upon the plant in producing such quantities of seed matters little in nature, as the individual is of no account so long as the continuance of the race is ensured—a fact which may serve as a lesson in social service. We have all seen the willow seeds transported by the wind and caught in vast quantities in every crevice in the neighbourhood of the trees.

It is difficult to overestimate the importance of this way of inculcating the methods of sexual reproduction among plants. Plants provide imperceptible steps along the systems of reproductive processes, from the flower that, possessing both anthers and ovary, may be self-fertilized, to the perfect cross-fertilization of the ovary of a female plant by the pollen of a male plant, which latter process differs but little from the fertilization of the ova of a highly developed mammal. We might go farther back still, and refer to the asexual production of the prothalli from which ferns are produced. We need to assist children to understand something of the beauty of sex at or just before the age when experience teaches us that children begin to inquire. It does not seem necessary to express surprise and regret that the clean and healthy atmosphere that may invest the imparting of knowledge and appreciation of sex is so often displaced, not by fairy-tales, which always have some foundation in fact, but by distortion and misrepresentation, whereby the innocent inquirer, unconvinced by what is told him (or her), prosecutes further inquiries at a source that is unwholesome. The child's ideas on the subject are befouled at the start, and unless some fortunate incident occurs may remain so to the end of earthly life.

Therefore it seems desirable to refer now to one of the most remarkable instances of reproductive processes among plants, and as we have dealt with a small plant (the wallflower) and a large one (the willow-tree) we may very suitably allude now to a water plant. Very common in southern countries of Europe is



VII. THE FLOWERS OF A FEMALE WILLOW-TREE

Photo H. R. Royston

the eel-grass, which is found in ponds and other still waters. Although it is not a native of Britain it is commonly met with here, because it is particularly suitable as an aquarium plant, and finds a place in most public aquariums and many private ones. For a shilling several specimens may be acquired from dealers in such material, and a male and a female specimen should certainly find places in every school aquarium. Eel-grass belongs to the order Hydrocharitaceæ, and is probably better known by its technical name—*Vallisneria spiralis*—than by its popular name, which is certainly less euphonious. In appearance, specimens of the two sexes are very similar, and their differences do not become apparent until their reproductive organs appear. The leaves are long and flat, like ribbons, and in twisting assume positions in the water that have earned for the plant its popular name. We may consider the flowers of the male plant first. They are borne on short stalks in clusters, each cluster being in its early stages enclosed in a bladder-like case, low down in the water, only an inch or two from the roots. The female plant, however, produces her flowers singly on stalks that grow to the surface of the water. In its early stages the female flower is also enclosed in a capsule, which persists until the stigmas have developed, but then disappears. The female flowers may be seen floating singly on the surface of the water, while the male flowers enclosed in clusters in their capsule are perhaps nearly a foot under water on a neighbouring plant. How then are the female flowers to be fertilized ?

We must examine the flowers in detail. The mother flower possesses a green perianth consisting of three sepals, beneath which is the ovary, and there are three comparatively very large stigmas. The male flowers, in the condition in which we find them at this point, consist only of buds, which now detach themselves from their axils and float to the surface, where they cruise about like little rafts, having apparently no interest in anything and not being sufficiently attractive to cause anything to take an interest in them. But in due season the three sepals open and fold back, disclosing two stamens, which project well above the water into the air. They now offer more resistance to air currents than they did in their unopened state, and may travel considerable distances at some speed. Eventually they are caught in little bays such as are formed on the surface of the water by vegetation or by irregularities of the banks of the pond, and many are merely sacrificed to that profusion of production which, as we have observed before, Nature practises to gain her end. But some become entangled among the flowers of female plants of the eel-grass, adhering to their stigmas, and the pollen from the anthers is contributed to these, thus effecting fertilization. The means by which the two sexes are brought together is remarkable, but at this stage something even more amazing happens : the object of the association of the two flowers having been attained, the thread-like stalks of the female are thrown into spirals that shorten their length, thereby drawing the fertilized flowers under water and down toward the roots of the plants, where the development and distribution of the seeds are carried out.

It is very important that the teacher should know a great deal more about his subject than it is, possibly, desirable and necessary to teach. The child whose interest has been aroused in the subject will quite likely prosecute investigations, so we may point out that we have considered only (i) plants which produce flowers that are ‘ perfect ’—that is, possess both stamen and pistil—and are self-fertilized ; (ii) flowers that are ‘ perfect ’ and are often cross-fertilized ; (iii) flowers that are ‘ imperfect ’ and possess only stamens or only pistils, but are borne on the same plant ; and (iv) flowers that are ‘ imperfect,’ the pistillate flower being borne on a female plant and the staminate flowers on a male plant. But Nature provides examples of all kinds of combination. It should, therefore, be observed that some plants bear flowers of two kinds, one of which may contain pistil and stamens and another only a pistil, while other plants bear flowers one of which may contain both pistil and stamens and another only stamens. All kinds of flower associations are possible and should be sought.

CHAPTER VII

MARRIAGE AMONG ANIMALS

THOUGH we cannot enter upon the subject of embryology—the study of the young animal or plant prior to birth—it seems worth noting that when, say, a mammal is born the sexual organs already exist. Certain cells of the mother organ are set aside for a reproductive process, and certain cells of the father organ are similarly allocated, and these cells in combination start the new generation. In describing the process in some detail so far as plants are concerned, we have really said all that is necessary regarding the reproductive process of animals. Since, however, the teaching of botany in schools does not appear to have met the requirements of sex instruction as had been hoped, and because it seems impolitic to confine our attention to plants as though after all there is something undesirable about the same processes in animals, it is proposed in this chapter to link up the two kingdoms and to show that the respective processes are the same in all essentials. At the same time we shall endeavour to indicate the general lines along which the instruction may be given. The writer believes that if an adequate course on botany is provided in schools, and the relation of plants to animals emphasized, all that is necessary has been done, so far as the ‘ thoughtful ’ child is concerned, but experience indicates that the difficulty lies in ensuring that sufficient stress is placed upon that relationship.

The line along which it appears we may make some progress is that of emphasizing that the production of eggs, or seeds, which have been fertilized is Nature’s way of propagating life.

Most children are acquainted with the hen's egg, and most know that if a hen's egg is subjected to certain treatment as regards warmth it will become a chicken, just as a wallflower seed subjected to the necessary warmth and moisture becomes a wallflower plant. The wallflower seed came from the body of the wallflower after it had been fertilized. Now all country children and most town children, if they have reached an age when they reason at all, know that the hen's eggs do not materialize out of thin air. As a matter of fact, it is probable that children do not, as a rule, begin to think much about these things until they are eight years of age or more. Such children have lived with chickens, or have spent their holidays in the country where chickens are kept; they have themselves extracted the warm egg from the nest, have seen the hen go there, and leave it with triumphant song—a hen has laid an egg and is very proud of the fact. Whence the egg came is not asked by, and is no mystery to, the child who has learned the lesson of the wallflower seed, but we want to direct his mind so that he may understand that the experiences of the young wallflower and the chicken have a very intimate association with his own existence, or at least we want to ensure that he has, by the age when he becomes interested in his own origin, sufficient knowledge of Nature and her ways to draw his own conclusions, and that these are right conclusions.

A lesson on the stickleback may prove one of the best means of developing instruction on the subject. The three-spined stickleback (*Gasterosteus aculeatus*) is the commonest of the species that exist in England, and by far the handsomest. It is hardly necessary to describe the common stickleback, because even town children know it. Sticklebacks are sacrificed in hundreds of thousands by children who have received bad instruction in nature study, which is worse than no instruction at all.

Thousands are extracted yearly from artificial lakes and ponds in public parks, packed into jam-jars, and taken away to die. They should have an aquarium to themselves in the laboratory, because they are pugnacious and wickedly aggressive, and will leave no other inhabitants of their little world alone. The male is a handsome little animal, but his beauties are not apparent when he is observed from above ; viewed from the side, however, his markings and colours appear to be similar and in no respect inferior to those of the mackerel. The female is more subdued in colouring, but is not sufficiently different to be mistaken for another species. The winter is the best time at which to stock the aquarium, and only a pair should be introduced into one vessel. If the fish are secured late in the winter there is little danger of mistaking the male and the female, for the female will already show signs of ripening ovaries in the considerable distension of the abdominal wall, while the male will have a red appearance below the gill-covers. As the weather becomes warmer, or as a result of the higher temperature in the schoolroom or laboratory, the red colouring will extend along the ventral part of the male fish, the gill-covers will turn iridescent with green and blue, and in due course he will become so highly coloured and handsome that people who do not know him intimately will at first refuse to believe he is a common stickleback. He will then be seen carrying about with him tiny sticks and broken pieces of weed, and breaking off pieces of weed if suitable material is not available otherwise, and these he will carry to the floor of the aquarium and stick them into the sand and *débris* there. He is building a nest, which consists of a number of tiny twigs and leaves set in the mud at an angle, crossing and supporting one another at the top, and he will continue this until he has made a covered receptacle nearly as large as himself. In the interval, during the building of the nest, he pays court to the female stickleback, and may be observed posing before her, violently vibrating his fan-shaped pectoral fins and then, with rapid twists of his tail, propelling himself through the water and coming to rest again within her view. The courting of sticklebacks, as of most animals, is exceedingly amusing : the female repels the male from time to time, and at other times pecks at him with her mouth. As the nest nears completion he may be observed obviously enticing her toward it. The development of breeding colour is an interesting subject, and is believed to be one of those processes of natural selection which Darwin propounded, a theory that has endured successfully many attacks and alternative propositions. The colour is probably due to increased activity of bodily processes, and the highest colours are therefore attained by the animals possessing the most robust health. Assuming, as seems to be the case, that the coloration is pleasing to the female, she selects as her partner the male which possesses the most festal appearance—that is, the one that enjoys the most vigorous health. This assists in ensuring that the progeny will have sound constitutions. Since like tends to produce like, the production of colour is perpetuated to the good of the race, the healthiest males securing partners, the others failing or having to take less vigorous females (for doubtless the females develop characteristics that appeal equally strongly to the males) the eggs of which are less fertile, and, if fertile, are less likely to succeed in life and give rise to fishes that are prolific.

When the nest is complete the male stickleback is free to devote the whole of his time to the courting of his mate, and ultimately he entices her to the nest, where she spawns, or, as we say, lays her eggs. Now the important thing to remember is that at this stage the egg cannot properly be compared to the wallflower's seeds as they are when the plant sheds them, because they have not been fertilized ; they are to be compared to the ovules in the ovary of the wallflower before the stigmas had been pollinated. Before the stickleback's ova become eggs that will develop into sticklebacks they too must be pollinated. We know that the pollen for the wallflower ovules came from an anther or male organ, so we shall have no difficulty in explaining to children that the pollen for fertilizing the ova of the female stickleback must be contributed by a male stickleback, as was the case in the willow-tree and eel-grass. How is this to be consummated ? Quite simply—in practice much more simply than is the case with most flowers. When the female stickleback has deposited the ova from her body, as the wallflower plant did the seeds from its carpels, the male enters the nest and extrudes its pollen, or, as it is generally called, its sperms, from its body, when the sperms make contact with the ova similarly as the pollen does with the ovules, and the ova become eggs in reality, capable, in suitable conditions, of growing up into sticklebacks like their father and mother. But the plant's eggs were able to fend for themselves, and the sun and the rain alone nursed them and contributed to their needs ; the stickleback's eggs, unlike the eggs of most fish, need attention, and this attention is given by the father, for the mother takes no more interest in her offspring except, it is said, that she would eat them if she were allowed so to do. But she would not be allowed to do this, even if she tried, because the father stickleback mounts guard and protects the eggs from the many hungry mouths that would make a meal of the contents of the little nest. He not only protects, but he also ventilates the nest so that the eggs may be able all the time to breathe fresh oxygen from the water. " Eggs breathe ! " children exclaim. Yes. Animals' eggs and plants' seeds breathe, because they are alive, and unless they breathe they will never develop. So the father of the sticklebacks-that-are-to-be constantly visits the nest, remaining there for quite long periods, fanning the water with his tail and pectoral fins and so causing currents that bring fresh oxygen, which, passing through the nest, aerates the eggs. He never leaves the immediate neighbourhood of the nest, and he attacks vigorously any other fish that comes near it, maintaining his vigilance until the young fish have developed sufficiently to break their way through the capsules of the egg-cases and come forth to commence life on their own account.

There seems no reason why the use of terms relating to botany should not be maintained throughout this instruction. When children, having become older, take up biology seriously, they will have to learn the correct names for the things with which they are dealing, but the practice of calling reproductive organs by names used ordinarily only in botany can never be confusing, and there will be some advantage. We have to choose between, on the one hand, teaching children the facts of life at an age when they first become inquisitive, and doing so along lines that they can take hold of by proceeding from the known and the understandable to the unknown and vague, and, on the other, leaving out half the instruction altogether, with the dangers that have already been referred to as attendant upon ignorance. In the latter case, we have at a later date suddenly to plunge them into consideration of phenomena with which they must deal in more advanced study and for which they are ill prepared. In describing the manner in which fertilization is effected in the case of a typical teleostean fish, it does not seem to the writer that any process to which the most delicate-minded person could take exception has even been broached. In what essential does it differ from the processes described in the case of the wallflower ?

We may proceed a step farther. In the spring masses of frog spawn are familiar sights in ponds and ditches in neighbourhoods untainted by industry of man and not devastated by the vandals whom all towns seem to harbour. Wherever there is sufficient moisture and cover, and no pressure of population on the open spaces, we find frogs, and where we find frogs we shall find frogs' eggs, or spawn, if we look in suitable spots at the right time. The spawn has the appearance of masses of gluten full of black specks situated at regular intervals throughout them. Each black speck represents an egg, and may be observed to increase in size day by day until the shape of the tadpole, which is the larval stage through which a frog passes in its development, is apparent. The primary purpose of the glutinous matter is to separate the individual eggs so that each may secure an adequate supply of oxygen. We often find that eggs and seeds contain substances that are not essential to the composition of a perfect egg or seed, but serve a secondary purpose ; we may remind ourselves of the comparatively large size of the hen's egg in contrast with the much smaller eggs of many larger animals, which is due to the fact that the egg has to provide food for the young animal for a long time before, and often for some time after, it emerges.

We do not think of the frog as a very sentimental animal, although a nursery rime places on record an instance of one that went wooing persistently. Frogs do go wooing, however, and sing love-songs when they are so engaged—indeed, the frog's croak, of which so many speak, but which so few take the trouble to hear, is used only during the breeding season. The male frog which has succeeded in his attentions to a female in the cold of early spring closely associates with her while the spawn is being laid, and as the eggs appear he emits pollen grains, or sperms, which unite with the ovules, or ova, of which the spawn consists, each ovum then becoming a perfect, fertilized egg, capable, given a fair chance, of growing up into a mature frog. When the spawn is produced the pair of frogs are in the water (in fact, during the breeding season frogs live in the water, but they do not take to the water at other times except to escape foes), and the spawn is passed into the water, where it swells up, the mass floating about on the surface. Neither father nor mother takes any more notice of it, and it is left to the oxygen and the warmth of the sun to finish the work. We shall have something further to say in a subsequent chapter regarding the metamorphosis of the frog.

In the cases of the fish and the frog we found that fertilization took place in a manner similar to that in which it takes place in plants, but in the case of the frog there is a more direct association between the male and the female. It seems that only one step remains to complete our story, and that this may best be accomplished by returning to the hen and its egg. Young children probably do not know that the eggs of a pen of hens unaccompanied by a cockerel would not produce chickens, but they will have formed a pretty shrewd opinion on the matter if they have learned the lesson contained in the previous pages. Since it is obvious that the pollen from the father fowl could not penetrate the hard shell of a hen's egg, fertilization must take place before the hard shell gets there. Consequently, the child's mind will be directed along right lines of thought by the explanation that the true part of the egg is the yolk, which, like all ova or ovules, is produced from an ovary, as in the wallflower, the stickleback, and the frog, and that the pollen grain must reach this part before the white of the egg, which is derived from the walls of the channel through which it passes, and the shell, which is deposited by the lower part of that channel, are wrapped round the yolk. By the time the child has reached an age when he desires to know exactly how this fusion of the pollen or sperm of the male bird with the ovule or ovum of the hen is effected he will doubtless have had many opportunities of drawing conclusions to which he will have been assisted by the instruction he has received already, and his thoughts on the subject will be wholesome, because they will be enveloped in the atmosphere of the story of the marriage of the flowers. The child's greatest difficulty will be the apparent inconsistency that some animals are born as eggs while others are fully developed animals at the time of birth. There are, however, parallel cases among plants; and seeds, especially of certain grasses on mountain heights, ripen and germinate, developing into young plants before they are detached from their parent and fall to the earth, when their roots find the soil. The action of other plants, such as the strawberry and the 'mother of thousands,' can also be touched upon, but these should not be pressed, as the production of young plants in this manner is not of a kind that we are specially considering, and is not the most common practice of Nature; moreover, it is adopted as an additional method—it does not displace reproduction by the fusion of male and female cells or gametes.

CHAPTER VIII

SOME DIFFERENT KINDS OF FLOWERING PLANTS

ONE of the most amazing characteristics of Nature is probably the diversity of the means by which she achieves her ends. We have defined life so far as we are able to do so, and have discussed the differences that exist between plants and animals, and so have discovered that there are more points in which they resemble than differ from each other. We know now that there are some organisms that botanists call plants, but which zoologists call animals, and others which both admit that each may claim with equal propriety. Excluding, however, those so-called ‘ border-line ’ cases, we know that there is a vast difference between the appearance of a little green alga and a walnut-tree, and between the microscopic animalcules that have built up our chalk downs and a herd of elephants. We may learn something, perhaps, by considering the diversity that exists between plant and plant and animal and animal, and by pondering upon the differences between organisms that now live upon the earth and those that once lived, whose previous existence is made known to us by the survival, more or less as fossils, of the harder parts of their structures.

We may be sure that in so far as one plant differs from another its differences represent an advantage to it, having regard to its particular environment. Some plants do not produce flowers : these are known as cryptogams ; while some—most of those with which we are acquainted—do, and are known as phanerogams. Why should there then be this vast difference, which is so fundamental as to divide the vegetable kingdom into two groups—flowering plants and non-flowering plants? We should not know were we not able to read the story of the rocks, read it though we do in a poor and halting manner. Their story seems to tell us that in the past plants did not produce flowers. At least, the evidences that exist of the vegetable life of earlier periods of the world's history show that the remains of past vegetation are the remains of plants that were related very closely to existing plants that do not produce flowers. There is, for instance, evidence that the ferns of past ages grew into large trees, with which the existing tree-ferns of tropical America form a link. We assume, then, that flowers are by way of being a novelty—speaking, we may say, geologically—and since they have become the rule, the exceptions being insignificant, we must suppose that the plants that first began to develop flowers acquired some advantage from them. Unless they did, it is difficult to account for the fact that flowering plants flourish over nearly all parts of the earth. Flowers have proved successful.

Flowers are not all equally beautiful, however, and it is not difficult to imagine that some of the earliest flowers produced were simple and unattractive—indeed, this must have been so. Probably we shall be right in assuming that the development of colour in the reproductive areas was a beginning, and that scent and nectar followed very tardily. It is almost certain that many of the pictures that profess to represent the forests that gave us our coal areas—visions of colour in which large-flowering cacti occupy the foreground, with aerial orchids in full bloom immediately behind—are mere flights of the imagination of unscientific artists. The plants that gave us our coal, it is now believed, consisted in the main of giant forms of some of the non-flowering plants that exist now—ferns and horsetails, which were propagated by spores, and not by seeds produced from flowers. The era of seed production was then only just opening. We shall see later how ferns do reproduce their kind. As a matter of fact, insects did not then possess the earth, as they now do perhaps more fully than any other kind of animal, and the purpose for which flowers exist would not have been very completely achieved. We know, or at least we ought to know, that many flowers are even now unattractive to our eyes, possessing neither brilliant colour, pleasant odour, nor attractive nectar, and we shall surmise correctly that these are flowers that are generally self-fertilized or fertilized by wind or water—flowers that do not depend upon insects, birds, or other animals to fertilize them. At the same time, we must avoid the danger of assuming that because a particular perfume is not attractive to us it is not attractive to some other animal, or that because a colour fails to excite our admiration it does not serve as a magnet to something else ; some plants even secrete ‘ nectar ’ that is repellent to human beings, yet invites the attentions of various animals.

It does not follow, however, that as a general rule any finality in the production of blooms has been reached or, indeed, will be reached. The comparatively unattractive flowers of many wind-fertilized trees may have found that they secured all they needed by remaining unattractive, or they may, many thousands of generations back, have been attractive flowers, pollinated by insects or birds. It may be that owing to changes in the quantity of pollen produced they have ceased to be dependent upon animal intermediaries ; since the wind stepped in, as it were, and took the place of such intermediaries the flowers may gradually have lost their attractiveness, there being no longer any use for it. And they would have lost it in this way. We have observed[1] that attractiveness is attained at a certain price ; if this quality ceased to provide the trees with an advantage, those that happened, accidentally as it were, not to waste their substance in acquiring it would be able to devote what they saved to strengthening themselves, and so to producing more flowers or more ovules to the same number of flowers ; they would, therefore, be more successful than the old-fashioned ones that continued to expend themselves upon the production of brilliant blooms from which no advantage was to be obtained.

---

[1] See Chapter VI.

We may now with advantage direct our attention to differences in the leaves of plants. We came to the conclusion[1] that the typical leaf is flat and is arranged on the plant with some relation to its fellows, so that it may expose as much surface as possible to the light, because only so can it make use of the carbon in the air in manufacturing its food ; and we found, too, that a water circulation is kept going in the plant by the root pressure and the transpiration of water from the pores, or stomata, on the leaves. Most leaves are flat, but if we consider for a few minutes we shall think of some plants the leaves of which are not flat and do not spread a large surface to the light, and of some plants that do not seem to possess real leaves at all, but merely a collection of spikes. When any plant bearing such ' leaves ' is referred to, we may assume almost with certainty that it is an inhabitant of either very dry or very windy places, or of places that are both windy and dry. It is possible that the first plant so poorly equipped with leaves to suggest itself to most of us is the gorse (*Ulex europæus*), one of the most handsome growths found in this country. Like heather, which also possesses strangely modified leaves, it is noteworthy not only for the colour of its individual flowers, but because it dominates vast stretches of country with a blaze of glory which, seen for the first time, stamps the occasion on most minds as one of the great incidents of a lifetime. Gorse certainly inhabits dry and windy wastes, the soil of which is poor and overdrained, and, as a rule, there is not much moisture to spare. Consequently, we can well imagine that if a gorse-bush possessed leaves like those of a fern it would have its water drawn off by the sun and desiccating winds at a rate faster than it could acquire it through its roots. To obviate this it has so modified its leaves that they offer not the greatest, but the least, possible surface to the air. But, it will be asked, does it not lose as much as it gains by this device, since it cannot make use of its leaves as a starch factory to the same extent as ordinary plants do ? Indeed it does, or it would except for the fact that its ingenuity in adapting itself to its surroundings is not confined to the modification of its leaves ; it also modifies its stem in order to make up for its loss of feeding surface. The stems of most plants of the size of gorse are woody and covered with cork, contain no chlorophyll, and have no work to do apart from their skeletal and vascular duties ; but the stem of the gorse is green, contains chlorophyll, and manufactures starch as busily as the leaves.

---

[1] See Chapter III.

The seedling gorse is not prickly, and thereby hangs a tale. It has been observed elsewhere that in development from the egg the individual to some extent recapitulates the history of life, and we may with some reason assume from this that the gorse is descended from ancestors that possessed flat leaves, and that the thorn-like processes of the modern gorse have been evolved from this more normal type. It is quite possible to account for the change in the following manner. In the course of time the ancestors of the gorse produced some young plants the leaves of which tended, as they grew beyond the seedling stage, to assume contracted dimensions, and these proved more successful than their fellows with more ample leaves, in that they could better withstand the drought and strong winds of their habitat. ‘ Success ’ means that they were more able than their fellows to mature and disperse their seeds, which, of course, developed a number of plants, some of which possessed economical leaves such as their parents had. Since the plants with this peculiarity increased at a greater rate than their relatives they would in time oust the less adaptive ones. Later, perhaps, plants were produced the leaves of which tended to develop pointed ends, serving as prickles that deterred animals from using them as food, and another advantage was thereby gained. In time the gorse plant thoroughly adapted itself to the conditions amid which it lived, and being more suited to its environment it gradually supplanted its less resourceful relatives.

We have learned how an ordinary plant gets its living, building up its body from the substances it obtains from the soil by means of its roots and from the air by the chlorophyll contained in its leaves and stem. One of the most remarkable departures from the normal manner of living adopted by some plants is that of parasitism. Children are generally taught that ivy is a parasite, but it is not a true parasite, because it does, in fact, work for its living in the same manner as do other plants, making use of its roots and leaves ; it is true that its mode of life is not always to the advantage of the plant it chooses as its neighbour, and in working for itself it does tend to deprive that neighbour of a certain amount of light and air, and to impose on it a weight which most plants have to bear for themselves. But it does not suck the ‘ life-blood ’ of its so-called host, and its adventitious roots are produced only for purposes of support. A parasite is an organism that lives upon or in another organism, which is called its host, taking nourishment from its host and giving little or nothing in return. There are many cases in which organisms live together assisting one another, as we shall see in another chapter,[1] and in some cases it is quite impossible to say that one derives more advantage from the communal existence than the other. In some cases, while each helps the other, one unquestionably reaps more advantage than the other from the association, and in extreme cases the advantage is all on one side. These extreme cases are cases of true parasitism. With increasing knowledge it is becoming more and more uncertain that no advantage accrues to the host from its parasite, and in dealing with the subject a certain amount of caution is desirable. Owing to this growing uncertainty, which has recently come into greater prominence from discoveries made regarding the work of certain parasites in the mammalian alimentary canal, some diffidence is felt in describing the mistletoe as a parasite, and in dealing with it here as a plant that ‘ preys ’ upon other plants. So distorted becomes the view based upon imperfect knowledge that a schoolboy is credited with having said that a cuckoo is a bird that does not lay its own eggs ; therefore we state here at the outset that it would be a mistake to suppose that a tree upon which mistletoe has taken root gives much and receives nothing from its association with its parasite. There are such parasites, but they are very degraded forms. Perhaps the study of parasitism provides one of the best moral lessons that can be introduced to a class, because it is possible to show that plants and animals that have given up an active life, living upon the work of others, are always more or less degenerate creatures. To such an extent is this so that it is possible to point to certain animals among the Crustacea that exhibit the characteristics of the higher members of their phylum in the earlier stages of their life-histories, and that after a period of free-swimming and food-seeking settle down as parasites upon other animals and straightway lose all their higher characteristics, absorbing the juices of their hosts and converting them into the substance of their own bodies without effort or will. The life-history of Sacculina, a parasite upon the crab, is a most remarkable instance of this, which the teacher can follow up and convert into a useful lesson on the dignity of work and effort.

---

[1] See Chapter XII.

Mistletoe (*Viscum album*) is a very familiar plant, though comparatively few people have seen it growing on trees. It is much commoner on the Continent, and large quantities are imported from the apple-orchards of Normandy just before Christmas. Male and female flowers are produced upon different plants, and in consequence the familiar white berries are found only on female plants. These fruits are the most conspicuous part of the plant, for the flowers are small, yellowish-green in colour, and unattractive in appearance. The leaves are of a very pale green. But so familiar is the plant that a general description is unnecessary, particularly since we are mainly concerned with its adaptation to a mode of life in which it has a great part of its work done for it. The berries contain but one seed each, and if we extract one we shall find that the viscous character of the fruit makes it very difficult to separate the seed entirely. This quality of viscosity is a device upon which mistletoe depends for its propagation, and it is probable that birds, and especially the thrush, are solely responsible for its distribution. Feeding upon the berries causes the beak of a bird to become much involved in the sticky substance, and it may be often noticed that thrushes, after feeding, rub their beaks along the branches of trees to clean them. It is easy to imagine that a mistletoe seed may be so transferred to the branch, where it adheres by virtue of the sticky pulp, and is not easily washed off even by rain. Now the radicle of the mistletoe seed, unlike that of others, does not always grow downward ; if the berry becomes affixed to the under side of a branch it grows upward ; in any case, it grows

VIII. MIDSUMMER: A WATER-LILY POOL

Photo G. W. Perkin

toward the branch, penetrates the bark, and so begins to draw nourishment for the young plant. This nourishment it obtains not directly from the soil, as a self-respecting plant does, but from the vascular system of the tree, and in this sense the mistletoe is a parasite. But we observed that the leaves were green, though not deeply green as are the leaves of most plants, and this colour leads us to suppose that they contain chlorophyll, and by testing them our suspicion will be confirmed. Since the leaves possess chlorophyll it is reasonable to suppose that they perform the function of securing carbon from the air ; as a matter of fact they do, and as they are evergreen, and are not shed in the winter, they go on producing starch at a time when their deciduous host has shed its leaves—in fact, they are more able to do their work then, because they have access to light that is shut off from them to some extent by the leaves of the tree among which the mistletoe lives, and are able to assist the resting tree at this period. It is probable, therefore, that the association of the two plants, the tree and the mistletoe, is not an altogether one-sided arrangement, and that the tree derives in the winter some benefit which can be set against the constant drain imposed by its unbidden guest. All trees do not harbour mistletoe. As has been stated, it is found most commonly on apple, but the oak and poplar are sometimes found bearing it, and the writer has found it growing on a lime-tree.

We referred to gorse as a plant that had specially adapted itself to dry and windswept positions. Let us now consider a plant that has found congenial surroundings at the other extreme, almost submerged in water, yet obtaining its carbon from the air and its energy from sunlight that falls directly upon its leaves without passing through water. The plant referred to is the white water-lily (*Nymphæa alba*), one of the most strikingly beautiful plants that grow wild in this country. Wonderful hybrids have been produced by crosses with exotic species, leading to considerable increase of size of the flowers and the introduction of delicate shades of red and yellow. The roots are firmly embedded in the mud of ponds and the backwaters of rivers, but the leaves and flowers push up through the water to unfold on its surface. Since the plant is frequently rooted at considerable depths below the surface of the water, the stalks are often of great length. It is a plant with character, and seen growing amid its natural surroundings creates an impression that does not readily fade. Pure, still, or very slowly moving waters alone suit it, and these surroundings add to the impression created. It is at home amid the lodes and peat-impregnated drains of North Cambridgeshire, group after group delighting the eyes of those who find there the joys of a quiet holiday with Nature. But it is widely distributed throughout Europe.

We referred to the water-lily as a plant so modified as not only to live but to flourish in aqueous surroundings. We have found that plants transpire moisture through their stomata, which are usually on the under side of the leaves. Now the leaves of the water-lily lie flat on the surface of the water, so that their under side is always wet, while the upper surface is exposed to the air and sunlight. Stomata would be of little use if they opened into water, and we find that it is on the upper surface of the leaves of the water-lily that we encounter them, in great quantities, estimated to number over ten millions to a leaf—millions of stop-taps regulating transpiration. But, further, we observe that the leaves are flat, with a raised lip all round their edge, and we must notice that the leaf is also raised at its junction with the stalk, forming a plane running down to the lip, and the lip is waved so that at certain points it does not interfere with the return of the water that may be splashed upon the leaf to the source whence

IX. WHITE WATER-LILIES (*Nymphaea alba*)

Photo G. W. Perkin.

it came. This device enables rain to run from the surface of the leaf to the water on which the leaf floats, and its passage is assisted by a waxy surface that discourages the accumulation of moisture. Yet another provision for the special conditions of life is that the under side of the leaf is generally purple in colour, due to the existence of pigment known as anthocyanine. This substance is found in other plants, and commonly in plants growing in damp places and at high altitudes. It has been demonstrated that it possesses the power of converting light rays into heat rays, and thus of assisting plants subjected to cold conditions to keep warm enough to carry out their work.

The white water-lily exhibits a colour scheme that appeals to human beings—large masses of green picked out in white and gold, but it is probable that it does not appeal particularly strongly to insects, which are not often seen visiting it. The flowers have little odour, and no nectar, but it is almost certain that cross-fertilization often takes place, for occasionally the flowers open before the stamens are ripe ; usually, however, the stamens fold over the stigmas, upon which the anthers empty themselves. The idea upheld by Goethe, and others, that each part of the flower of a flowering plant is a modified leaf, has been said to be illustrated by the water-lily, but this theory of the origin of flowers is now regarded as erroneous. Consideration of some of the plants that at present exist certainly seems to disprove it. We shall examine this more fully in Chapter XVI.

Nevertheless, it is worth while to observe the green-brown sepals of the water-lily, the green-white sepal-petals, the pure white petals, and the smaller petals with their yellow ridges which surround anthers mounted on stalks that look like modified petals ; then the stamens bearing other anthers, and, in the centre, the large box-like ovary. Each of the chambers into which the pistil is divided bears a stigma and contains seeds, the whole fruit consisting of some sixteen fused carpels. There are four green sepals, and of the petals eight are thought to be true petals, the remainder being secondary ones which were possibly stamens at some stage of the plant's evolution. The whole flower becomes waterlogged in time and turns black, while the enlarged pistil rots away from the flower stalk and sinks. When the pistil disintegrates the seeds come again to the surface, rising by means of the gases that are generated in their integument as it decomposes, are separated, and secure dispersal by means of floods and birds. When the gases are liberated the seeds sink again to the bottom and should in due season produce plants that have existences as successful and gratifying as their progenitors had. Like the gorse and many other plants, the water-lily begins life with leaves quite different from those of the mature plant. Slender grass-like foliage gives place first to oval and then to sagittate leaves, and in consequence the identity of the young plants is often not suspected.

There is no limit to the amount of differentiation between plants resulting from their adaptation to different modes of life, for whether we consider the arid wastes of the Sahara with their cacti, and such restricted deserts as exist in our own country in the form of slated roofs and stone walls with their houseleeks and stonecrops, or whether we explore the watercourses of East Anglia with their wealth of aquatic, semi-aquatic, and land flora, we find everywhere that plants—highly developed plants—have devised means of adapting themselves to the special conditions existing. We can hardly do better in concluding this chapter than refer to one of the most frequently encountered plants that exist, found in almost every part of the globe that man has trodden. It follows in his footsteps and marks the places in which he has had his habitation long after he has abandoned them. Notwithstanding its close association with man, man does not love it—indeed, he finds it a very unpleasant acquaintance at close quarters, for it is armed with a thousand bayonets. So common is it that it has been said that it may be found merely by feeling for it, even on the darkest night! The plant in question is the stinging nettle (*Urtica dioica*).

The amazing frequency with which the stinging nettle is encountered is due in part to its love of highly manured ground, and it finds the richly nitrogenous soil of lands close to the habitations of man particularly to its liking. As a plant for school study it possesses one serious disadvantage—it cannot be readily handled; but it is worthy of examination *in situ*. It has been chosen for inclusion in this chapter because of its singular method of defence. Most children know it well, but do not, as a rule, know how its defensive armour is devised or anything of its manner of living. In passing, it may be observed that it is the food-plant of two very beautiful butterflies, the peacock and the small tortoiseshell, and that the bodies of their caterpillars, which doubtless secure some protection from their host, are covered with a number of spiny processes which have not, however, the power of penetrating human skin or of inflicting injury such as that inflicted by the very much smaller spiny processes of the food-plant itself. The stinging nettle is a perennial plant—that is to say, it does not die in the autumn when its growth is arrested by the withering of the leaves. The living processes retire to the roots and underground shoots, and new shoots spring up early in the new year, evidence of creeping rootstocks that provide the means by which the plants extend their kingdom. They are, however, also propagated by seeds, and the rootstocks must, therefore, be regarded as ancillary to this, the normal, method of reproduction.

There is really no excuse for confusing the stinging nettle with the white dead-nettle (*Lamium album*), which, by the way, is not a nettle at all, but has acquired its name from a fancied resemblance to the stinging nettle. This resemblance is a very superficial one, and is confined to a rough similarity in the general outline of the leaves. The leaves of the true nettle are, however, more sharply pointed and indented, and are covered with a number of hairs that point toward the apex of the leaves and are the stinging organs. In most respects the two plants differ widely—in the shape of their stalks, their life-histories, and their flowers. If, notwithstanding, doubt still exists whether a plant is the one or the other it can, as has been said, be felt !

As this chapter is devoted mainly to consideration of the most striking differences between certain plants, we should confine ourselves to the stinging mechanism of the nettle, but the plant is worthy of notice for other reasons which we should not ignore. First, it is like the willow in that each plant is definitely either a male or a female, since both stamens and pistils are never found in the same flower, neither are male flowers and female flowers ever found on the same plant. The flowers themselves are disappointing if we regard them merely from a spectacular point of view, but by now we have probably succeeded in convincing our children that things are not interesting only when they seem to us to be beautiful, and that often objects that at first glance do not appear very beautiful on examination provide us with visions of beautiful mechanism and skilfully devised processes. If we have succeeded in so doing, the flowers of the nettle will not disappoint the class, but they are so small that they cannot be handled for examination by children. Children can, however, learn with advantage that the tiny green father flowers of the nettle carry out their functions as effectively as the big gaudy yellow male flowers of the vegetable marrow, which may be obtained at the same time, as can also the respective mother flowers ; the male flower of the nettle indeed possesses an arrangement for disseminating its pollen which the marrow flower does not possess—its stamens have the power of considerable movement. The flowers form catkins, and plants bearing staminate flowers may be distinguished readily from those bearing pistillate flowers, because the catkins of the former are smaller and lighter in colour, both, however, exhibiting homely shades of green. The individual flowers are exceedingly simple as compared with most others. The male flowers consist each of four sepals and four stamens with anthers, and the female flowers each of four sepals with a central ovary bearing a hairy stigma. When the sepals of the male flowers open, the long stamens are folded over so that the anthers approach the centre, where is what may probably be considered as a vestigial ovary, but as soon as the air is dried by the sun and the anthers open the stamens spring outward, the shock causing the anthers to discharge their pollen like little balls of buff smoke. The discharge of the pollen may be witnessed by any who are prepared to stand by a bed of nettles as the sunlight approaches it. Each discharge is like the bursting of a tiny shell, and as the action of the sunshine in drying the air becomes more effective the explosions become more frequent until the ripe flowers have all unloaded themselves. The female flowers are wind-pollinated, since there is no intermediary other than the air. Even without observation we may assume that there is an extravagant production of pollen, but its abundance is necessitated by the amount of waste that always accompanies wind-pollination.

It is not generally known that fibre of the stinging nettle was widely employed as a textile prior to the production of flax and hemp as articles of commerce. It is said that in many respects it is hardly inferior to flax, and that during the War, when the Germans were shut out of the flax markets and could not grow sufficient flax for themselves, they encouraged the production of the nettle and made therefrom their ‘ linen ’ for aeroplanes. This may easily be believed if nettle stems be ‘ scutched ’ as flax is—that is, macerated in water until the softer parts have broken down, and then scraped ; tough filaments will remain, closely resembling raw flax.

But, after all, the most outstanding feature which has earned for the nettle its notoriety is its stinging propensity, and it owes this to the hairs with which the leaves are covered. They may be seen with the naked eye. If the finger be placed near the base of a leaf and the leaf be stroked gently toward its apex it will be found that no effect is produced upon the skin of the finger—the nettle does not sting. But let the movement be in the opposite direction—the direction in which the ‘ stings ’ point may thereby easily be demonstrated. If a leaf be pressed between the thumb and finger no untoward incident is experienced by the investigator, because the ‘ stings ’ are merely pressed down and broken off, and to that extent the nettle, and not the finger and thumb, suffers. What are these ‘ stings ’ or hairs ? A microscope is necessary properly to appreciate them ; so examined they may be seen to be tubes, each of which arises from a tiny bed of special cells. They owe their ability to penetrate the skin to the fact that they are strengthened by flint, or silica, and their capacity to sting and to cause swellings is due to the liquid in their hollow interiors, for this liquid contains formic acid and is similar to the gift received from an over-attentive ant or an angry wasp or bee. We have, then, in the nettle a plant that employs a scheme of defence that has also been adopted by a number of insects. At one

X. NEMO ME IMPUNE LACESSIT!

A white thistle. The foliage discourages the attentions of many—but not all—animals.

Photo C. H. Royston

time the nettle, cooked, was regarded as a valuable table vegetable, and it is, as has been observed, the food-plant of certain insects. How far its powerful defence has resulted in loss of favour as an article of diet cannot be said ; possibly a time arose when the penalty its gathering imposed ceased to be justified by the price obtained for it, but we must assume that its formidable array of hairs has protected it from becoming the food of many higher animals, and that in consequence it has been better able to propagate itself. The effect of the defence cannot be studied if consideration is confined to the growth of the plant to-day and in this country. Among more primitive and less clothed people it is clear that it would be avoided, for a man with bare legs would not deliberately walk through nettles unless he were impelled by a very strong motive. As is usually the case, close relatives of plants and animals indigenous to this country attain greater dimensions in warmer climates, and nettles are no exception to the almost universal rule ; some nettles produce much larger and more venomous stinging hairs, and against these black and thicker skin is no protection.

In the south-eastern counties of England the Roman nettle (*Urtica pilulifera*) may sometimes be found. It is common in the warmer countries of Europe, and is said to have been brought to England by the Romans with a view to the stimulation of their southern circulations against the cold of our barbaric climate, and that they used the plant as flagella upon their bodies. This plant is much more virulent than our own, and when it is encountered the more poisonous qualities of exotic species may easily be demonstrated. In some countries nettles may prove dangerous to life, and these must secure considerable protection against animals not specially adapted for their destruction by the possession of horny mouths, or flesh resistant to the effects of the poison.

THE UNITY OF LIFE

We have considered a number of plants each of which differs from the others in some striking manner, and is adapted to a particular mode of life or has provided itself with an extraordinary means of protection. The examples have been chosen from the flora of our own country, because for teaching purposes it is clearly inexpedient to increase difficulties by demanding unfamiliar specimens, or to depart from the principle that ocular demonstration should always form part of the lesson. Moreover, the greater the familiarity of the student with the plants and animals of his own country the less perplexing do the wonders of other climes appear to be. While our own land is so richly endowed both in numbers and variety it seems to the writer undesirable to introduce to children examples from abroad, except in passing reference.

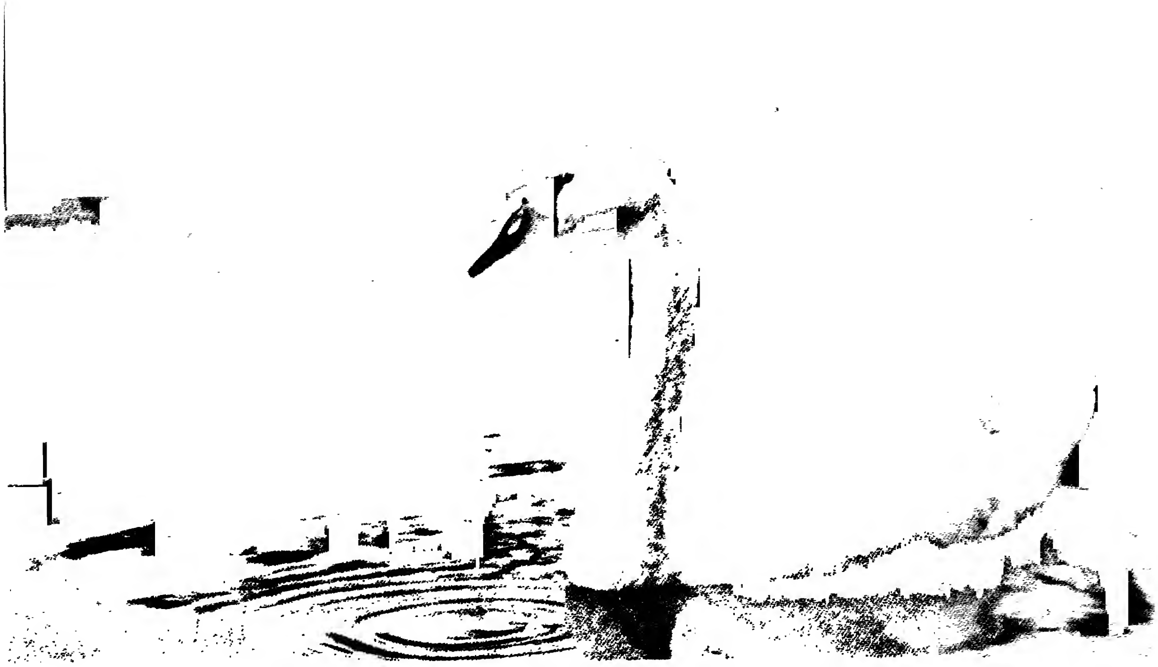
CHAPTER IX

SOME DIFFERENT KINDS OF ANIMALS

IT is not possible to say that animals show a greater diversity among themselves than plants, because between the lowest and the highest forms of plant life exist a number of divergencies quite as great as exist between the simplest and the most highly developed animals. We did not secure a very clear view of the kingdom of plants in Chapter VIII, because we definitely confined ourselves to consideration of flowering plants, which constitute only part of that kingdom, in order that we might later give adequate attention to some of the non-flowering plants. If we similarly restricted ourselves in this chapter we might have to confine ourselves to, let us say, the placental mammalia, or perhaps, for the sake of simplicity, the mammals. This it is not proposed to do. Animals, because they are more active, attract our attention more than plants do, and we notice their differences more exactly, but if we rightly consider them we shall be forced to the conclusion that plants exhibit just as important differences, just as wonderful a fitness for different environments, and just as interesting life-histories as animals.

Starting from the rabbit, to which a chapter has been devoted and which we may now assume to be the animal with which the children are best acquainted, we may proceed to consider a bird. Let us choose a pigeon, a specimen of which may easily be obtained and brought to school in a cage. Here we have an animal very similar to the rabbit, its differences being more apparent than real. Its skeleton is built on the same lines as that of the rabbit, but with such modifications as are called for by its mode of life, which is spent partly in the air, often for hours at a time.

What are these modifications ? It is much to be desired that a mounted skeleton of a flying bird be exhibited in class. Museum authorities, who recognize that the teaching functions of their exhibits need not be confined to visitors, will sometimes loan to an accredited teacher any specimen of this type they possess. If a similar exhibit of the skeleton of a small mammal is obtainable the utility of the skeleton of the pigeon will be considerably enhanced. A pigeon is heavier than air—that is to say, it is heavier than the amount of air it displaces, or heavier than the amount of air that could fill the space occupied by those parts of its body that are not mere receptacles for air. How, then, can it be sustained in the air ? To start with, most of its bones are hollow and filled with air, whereas the bones of non-flying animals are either solid or are filled with ‘ marrow ’ ; further, its body is packed with air sacs, or frail bladders full of air ; and, finally, the feathers, which take the place of the fur of the rabbit, are cunningly devised not only more effectively to protect the bird from cold—and a bird, having a higher temperature than a mammal has, needs more adequate protection—but to do so with the minimum of weight. Their shafts are hollow or contain only a pith-like substance that is light as thistledown. But, further than this, the shape of the bones of the fore-limbs is so modified as to form with the muscles and feathers with which they are clothed a plane that offers resistance to the air. When we were considering the dispersal of the seeds of the wallflower we threw into the air some cardboard disks to show how the air, offering resistance to their weight, caused them to travel, and if this lesson was understood the class should be well on the way to an under-



XI. A Swan (*Cygnus olor*)

A bird adapted for life on the water and in the air.

Photo C. H. Royston

standing of the method of a bird's flight. It rises, and keeps its level, by flapping its wings, but its propulsion is due to the effect of the planes formed by the wings. Considerably more attention has been given to the flight of birds since the aeroplane or ' heavier than air ' flying-machine began to develop ; the use of ' gliders,' or flying vessels not equipped with a motor, has led to much scientific observation of the manner in which the flight of birds and other animals is effected. The following facts have been established : the forward movement is produced by gliding, which can take place only in the event of there being initial velocity, and ordinarily it involves loss of altitude ; in gliding the wings are held motionless, and the speed is increased if they are arched ; for soaring the greatest possible expanse of wing is employed, and it is made possible, or at least assisted, by air currents ; change of direction is the result of partially closing one wing, not, as is often supposed, of any action of the tail ; indeed, the tail produces little effect upon flight—and we have only to look round to see that many birds with large tails are indifferent fliers. Observation of a bird's flight is a fascinating pastime, and children may be encouraged to take advantage of the many opportunities that offer themselves. They may notice how beautifully the flight feathers support one another and so prevent too much air from passing between them ; and, by means of a lens, they may examine the barbs interlocking, and also, if a microscope be available, the structure of the barbs and barbules. There is yet another modification to which the power of flight is due—the development of a deep keel on the sternum, or breastbone, to which the comparatively large pectoral muscles are attached. These powerful muscles manipulate the wings, and it is worth while noticing that, notwithstanding their strength and powers of endurance, they form the ' breast ' of the bird, which is regarded at table as the tenderest and choicest morsel of the poultry course. The development of the aeroplane owes everything to intelligent observation of the flight of birds. But a bird is a more perfect flying-machine than an aeroplane, and probably will always be so, because its wings conform more exactly to its will than the planes do to the will of the pilot, who has to transmit it through his 'joy-stick.'

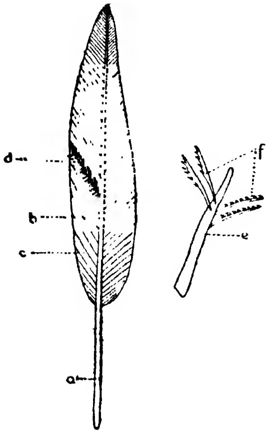


FIG. 17.—The parts of a feather shown diagrammatically. (*a*) Quill. (*b*) Shaft. (*c*) Barbs. (*d*) Barbules, shown only on one barb. (*e*) A single barb showing (*f*) two fore and two aft barbules.

We already know something about the means by which the pigeon reproduces itself, because in Chapter VII we considered the production of eggs. There is no external evidence of the sex of a pigeon other than slight differences of plumage and of the wattles at the base of the beak. We know, however, that the female must possess an organ for the production of ova and that the male is able to produce fertilizing elements, or sperms, or, as we called these bodies when dealing with plants, pollen grains, which are introduced into the eggs before they are laid. A characteristic of the eggs of birds, we have observed, is that they possess great store of food material, but it is not a characteristic that is peculiar to birds, because the eggs of reptiles are similarly supplied. Birds resemble reptiles very closely, much more closely than do mammals, although both birds and mammals have developed from reptile-like ancestors.

The internal anatomy of the pigeon, which is in this respect typical of birds generally, is remarkable for its digestive canal.

We have familiarized ourselves in some detail with the digestive system of the rabbit, and in general that of birds is similar. But it possesses an important modification due to the absence of teeth, in consequence of which food is generally swallowed whole, the only attempt among birds at mastication being the crushing of their prey by insectivorous birds and the tearing adopted by birds of prey ; in these cases, however, the modification of the alimentary canal is not so pronounced. In the cases of most birds the food is swallowed whole, and the pigeon eats hard peas and maize, which an inspection of its beak shows it to be quite incapable of triturating. These pass into a sac called the crop ; after a bird has had a meal there is an obvious swelling at the base of its neck, where the crop is situated. Here the food remains while it is softened by the absorption of moisture, after which it travels to the true stomach, or gizzard. The gizzard is a very remarkable kind of stomach. We learned in Chapter IV that it is very important that the rabbit should properly masticate its food before it is passed to the stomach, and we know that the pigeon cannot masticate the corn it eats. Now if we examined the stomach of a crustacean animal, such as a lobster, we should find that teeth had been placed there instead of in its mouth—three beak-like bodies that tear and grind up the food in such a manner as to have earned the name of 'the gastric mill.' There are, however, no such teeth in the stomach of a bird, and as the food must be ground up, since its sojourn in the crop has only softened it and not even broken it, another method has been devised—the pigeon just imports teeth as it requires them and passes them into its stomach ; it swallows little stones that act as veritable millstones, that are retained in the stomach and, owing to the regular contraction and expansion of that organ, serve to grind up the corn into a paste, in which condition it can be acted upon by the gastric juices and converted into substances that can be absorbed by the alimentary canal. The fact can be demonstrated, and the method of working explained, if the gizzard of a chicken or turkey be obtained from a poulterer and opened in the presence of the class.

There are other modifications in the internal anatomy of birds that belong to the more advanced science of comparative anatomy, but these would carry us too far along a particular road ; the teacher and class will find in nature study, as in most other subjects, that the deeper they probe the more numerous and intricate will be the problems that present themselves. The earnest student of nature will early become specially attracted by some particular aspect of the subject—natural history, physiology, evolution, or one of the new branches constantly being raised to the dignity of a subject in itself. These pages aim at inculcating an appreciation of the problems of life and their relation to one another rather than at offering solutions, and at evoking that interest which will arise in the minds of many children if they are taught at least the minimum that they ought to know about living things.

Before leaving the pigeon, which has been chosen as a particularly suitable example of a flying animal, it should be observed that true flight is possessed only by insects, birds, and mammals, and among the last group only by bats. Now these groups of animals resemble one another in the care they exercise in the interests of their young. Most animals lay their eggs amid suitable surroundings and then take no further interest in them ; in fact, this important function having been performed, the parents die in some cases. It is not suggested that there is any connexion between flight and parental solicitude for offspring ; it would be a wrong conclusion, because many flying insects take no interest in their eggs once they are laid

—moths and butterflies, for instance—while flight is rare among mammals, all of which exhibit bountiful interest in their young. But there must surely be a connexion between this well-developed parental instinct and the success of the animals that possess it. By success is meant the very firm hold these animals have on the earth's surface, their numbers and wide distribution. Insects have a very long history, and their origin is very primitive ; reptiles once flourished and were predominant, but are represented mainly by feeble descendants now ; birds and mammals have succeeded reptiles, and are digging themselves more and more securely into their possessions. The old Judaic Law shows a wonderful knowledge of biological truth such as can hardly have been acquired except by revelation. May it not be that the honouring of parents was recognized as the result of parental care, and that this is really the condition attaching to the promise of length of days, a promise made, surely, not to the individual but to the race ?

In the rabbit we have an animal fitted for a life on and in the earth, with limbs adapted to progression in such surroundings. In the pigeon we have an animal that can move about easily and comfortably on the earth, but so modified that its maximum grace and ease of movement are exhibited when it is in the air. It seems fitting that we should now pay some attention to a fish, which, compared with a rabbit or with ourselves, exhibits modifications even more remarkable than those of a bird. We have already considered the stickleback, but we ought now to choose some larger species, so that detailed examination may be easier. Fortunately our own fresh waters abound with a variety and number of fish from which we have ample opportunity of selecting suitable examples, but as we see them more often alive than dead the teacher will prefer to go to a fishmonger and procure a good fresh herring (*Clupea* *harengus*) to introduce to his class, because it is a recognized food-fish, and an exhibition of apparently needless slaughter will thereby be avoided. It would be well, however, to deal only with piscine characteristics that are common to the vast majority of fishes, and to avoid the special ones of the herring, few though they be. Fish, like all other animals, breathe in oxygen and give off carbon dioxide, but they draw their supply of oxygen from the water, which, as we learned in Chapter III, consists of oxygen and hydrogen, instead of from the air. If a bird or a mammal, or any animal that breathes in the air, is held under water it dies, as we know, by drowning ; the water enters the lungs, which are unable to absorb the oxygen from water, because they cannot make use of it in a liquid state. On the other hand, we know that the fish with which we are dealing died because it was taken from the water into the air, from which it was unable to absorb the oxygen necessary to purify its blood so that its body might breathe. Obviously, then, there must be a remarkable difference between the fish on the one hand and the rabbit and the pigeon on the other, and that difference is most likely to lie in the structure of the breathing organ, as, indeed, it does. But a fish does not possess lungs. We know that breathing must take place, and in the absence of spongy, porous bodies such as lungs we have to ascertain how the oxygenation of the blood is effected. Although it is effected in a manner similar to that in which air-breathing animals effect it, the details are quite different. We found that lungs are bodies into which a number of canals ramify, and that into these canals the air is drawn and is expelled when it has served its purpose. Now fish breathe by means of their gills, and these organs differ from lungs in that they are, as it were, the canals of the lungs, which project into the oxygenating fluid, the water. We can easily examine them in our dead herring.

They are red, filamentous organs, into the detailed structure of which we cannot enter. But we can grasp their general working and must understand it if we are to appreciate their adaptation to the requirements of the environment in which the herring lives. It is clear that if fish breathed by means of lungs the formation of gas in the smaller tubes would prevent the entry of water, and we find that the gill filaments exist in their stead, offering, owing to their fineness, the greatest possible surface to the water, enabling the blood that flows through them to give up its carbon dioxide to the water as the blood of the rabbit did to the air, and absorbing the oxygen dissolved in the water. Owing to the fact that the heart of a fish consists of two chambers only, the blood is pumped to the gills, which pass it on to other parts of the body and not back to the heart as we saw is the practice in the rabbit ; in consequence the heart never contains other than impure, or venous, blood. No teacher who has the opportunity of presenting these facts to a class, and who has seen multitudes of small fish crowded into a jar of water, will miss the opportunity of pointing out the cruelty involved in keeping fish in water in which the oxygen is not constantly renewed. We have all, unfortunately, seen goldfish gasping at the surface of so-called aquariums ; they have used up so much of the oxygen that they cannot properly breathe, and have come to the surface, where the water is able to absorb a little oxygen from the air. In a properly equipped aquarium in which water plants are growing a balance is maintained, and the water is kept oxygenated by the oxygen given off by the plants,[1] and unless plants are growing therein an aquarium should be furnished with a drip supply or a fountain. Even so, it should be understood that if the fish come to the surface and remain there with their normal rate of respiration increased it is evident that something is wrong. It is easily observable that fish open their mouths regularly, not to drink water, as is often supposed, but to allow the water to pass over the gills and out from the gill covers.

---

[1] See Chapter III.

Another remarkable adaptation of the fish to its environment is the general shape of its body. Children will offer the suggestion that it is like a boat or a submarine. It is true that boats and submarines have been shaped to follow the general lines of a fish's body, but it is obvious that the fish is as much superior to anything man has made to share the waters with it as a bird is to an aeroplane. There are no projections on a fish's body to offer resistance to the water. The organ of locomotion is the tail, and in most cases the fins have no share in the production of power for propulsion. This may readily be demonstrated by observing fish in a rectangular aquarium; a globular aquarium is useless for observation purposes, because it distorts. Those who have paddled a Canadian canoe will appreciate the amazing capacity for adjustment whereby the tail offers resistance to the water with a view to the development of power, and reduces this resistance when the movement is designed only to bring the tail again into a position from which it can be used to drive the fish forward. The fins serve mainly as balancing organs, but they also appear to be of service in enabling the fish to adjust its position in relation to the surface of the water. Most fish possess an air bladder, which makes them buoyant, and this, a very remarkable organ not possessed by any other animals, is the forerunner of the lungs of other animals. It contains gases that enable the fish to adjust itself to the varying pressure at different depths. The development of a pair of lungs from an air bladder is a part of the study of comparative anatomy, but it does not require a very vivid imagination to see its possibilities, and there is no longer any doubt that the air-breathing organ was so evolved.

The scales, remarkable modifications of the hair and feathers of mammals and birds, so fitting as to effect their purpose without offering resistance to the water, are worthy of notice. To most of us a fish-scale is just a fish-scale, but to the trained ichthyologist the scales are a guide to identification, though perhaps not so unfailingly as a leaf identifies the plant from which it is derived. They have their origin in the inner skin, the dermis, but are covered by the outer skin, the epidermis, which, as in ourselves, is non-living matter that is constantly being worn away and replaced. In fish the epidermis is a slimy covering, which does, as a matter of fact, contain cells of living matter that secrete the slime and make good the losses that are sustained.

A popular pastime with children who find a fish's head on their plates is to dissect it, and on these occasions the hard white (when cooked) lenses of the eyes appear as most conspicuous objects. It is surprising that the lens of the eye should be so completely spherical, until we recollect that water has a high refractive power, when it becomes obvious that the curvature of the lens must be great. We can appreciate this although we cannot profess to know what kind of vision a fish possesses. The fact that a fish cannot close its eyes should be noticed.

Fish differ from both mammals and birds in that they are 'cold-blooded.' We should understand that a warm-blooded animal is one the temperature of which is fixed for its particular species, any variation indicating a pathological condition, whereas the temperature of so-called cold-blooded animals varies with the temperature of their environment. In the summer a fish's temperature is higher than it is in the winter, but it is always lower than the temperature of mammals and still lower than that of birds. Now we know that the warmth of a mammal's body is the result of combustion,[1] in which oxygen plays a part, and as a fish's temperature is lower than that of a mammal we shall rightly assume that combustion is at a slower rate than that of the mammalian body. The fact is that, owing to the simple character of the heart of a fish, the blood does not reach the whole of its body so completely oxygenated as it does in a mammal. But this belongs to comparative anatomy—the evolution of the mammalian heart—so we must content ourselves with the acknowledgment of the fact.

When we studied the stickleback in Chapter VII we dealt with the subject of the fertilization of the ova of fish, and we need not go into it again here, except to remark that the herring does not show the paternal solicitude for the welfare of its offspring which we noticed in the stickleback. The fertilized eggs are left to fend for themselves, but they are produced in such vast quantities that they successfully withstand the wholesale destruction they meet with from every conceivable source, and as a race maintain their numbers. There is still a great deal of mystery surrounding the life-history of the herring, and at present its apparent diminution of numbers, or partial forsaking of our coasts, is causing some concern among those who depend upon its capture for a living. It should, however, be remarked that, although the herring is one of the commonest types of fish, there are among fish themselves some curious modifications in shape and habits of life. The so-called flat fish can be arranged in two groups : there are (i) those which, like the skate, appear to be flattened as from above and below—but the skate is a very different fish from the herring, and represents the more primitive cartilaginous fish ; (ii) those like the plaice, which are flattened laterally ; and seem almost to have lain upon their sides while they were flattened out, after which one eye came round or worked through, so that both reached the dorsal surface. Then there are elongated fish such as eels, the life-history of which was so wrapped in uncertainty at one time as to earn for them special chapters in natural history books on " The Mystery of the Eels." Then again there are fish like the climbing perch (*Anabas scandens*) of Ceylon that can traverse dry land, and ' flying ' fish, very similar to the herring, which make gigantic leaps and plane through the air by the aid of their pectoral fins—which is not true flight, however. Most remarkable of all are the ' lung ' fishes, different species of which are found in South America, Australia, and Central Africa. In these the air bladder is so modified as actually to act as lungs, and these fish breathe both by gills and lungs. When the water dries up, two of the three known species bury themselves in the mud, form a cocoon of slime with a little door at the top, and rest until the floods return ; during the resting periods they breathe oxygen from the air by means of their lungs. When the waters melt them out, as it were, they resume the use of their gills ; but even then they do not rely entirely on these organs, but come to the surface from time to time like an amphibian such as the newt, or a mammal such as the whale, and inhale a quantity of air. There can be no doubt that we observe in these creatures a true link between ordinary fish and higher forms of life such as the amphibians and the reptiles, and as such links are very rare they are all the more valuable and worthy of study.

---

[1] See Chapter IV.

The teacher will desire to have indicated to him steps by which he can work back to those simple organisms which we have decided cannot with accuracy be described either as animals or plants and must therefore be considered as true plant-animals. The animals we have been considering in this chapter all possess one characteristic—a backbone distributed dorsally along their long axis. When we attempt to link up the vertebrates and the invertebrates we enter upon a troubled but intensely interesting study—troubled, because we early become confronted with a number of theories which have been advocated, each of which appears to offer a plausible solution until a more plausible one is put forward ; interesting, because we can find just sufficient to encourage us to imagine we see links that carry us back to much simpler types. But in the end we are always met by some serious difficulty that leaves us much where we were and forces us to a conclusion that whenever animal life branched out along lines of differentiation it was very, very long ago, and that the evidences in the way of true connecting links have either been destroyed by time or remain still hidden away in Nature's secret drawer, the rocks. In examining different types of invertebrate animal we can go no farther here than to describe their adaptations to their surroundings.

Omitting one or two widely differing animals from among which we may some day discover the progenitors of the vertebrates—one of which, by the way, possesses a large amount of cellulose, a vegetable substance—we should perhaps first consider the echinoderms, the most familiar of which is the starfish (*Asterias rubens*). Echinoderms are described by the zoology text-books as "bilaterally symmetrical animals that have acquired radial symmetry." They pass through metamorphoses in which they exist first as bilaterally symmetrical larvæ, subsequently changing to the star-like form in which they attain maturity. The ordinary starfish of our coasts is a very common animal, the slow movements of which are familiar to all of us, particularly in our youth. There are five arms, or lobes, each of which possesses as its tip an eye-spot, which is probably capable of distinguishing light from darkness, but of little else. The ' fish ' (it is not a fish, because, as we know, it has no backbone, and fish are vertebrates) is able to carry out every imaginable contortion, and can even extrude its stomach through its mouth and then turn it inside out preparatory to engulfing its food. It secretes itself in fissures in rocks, and the flesh-coloured bodies observed between tides are often taken to be something other than they are until they are drawn forth, often with senseless force, when the limbs gradually unfold. The ventral surface of a starfish is much more interesting than the dorsal, because there are the tube-feet situated in grooves along the rays, very numerous and very efficient. The tube-feet are extremely interesting, because they act as suckers, and their combined efforts, which are capable of being long sustained, succeed in tiring out the inmates of bivalved shells such as mussels and of forcing apart the valves of the shells, when the mussels speedily become food and are transferred to the stomach of the starfish. Each tube-foot is hollow and communicates with a space in the ray which runs throughout the whole of its length and connects with a water-vascular or circulatory system. When the water is pressed toward the ' feet ' they form flat disks upon the stone along which the animal desires to move or upon the shell it wishes to open ; then, again by muscular contraction, the water is pressed back into the canal, drawing the centre of each disk up and creating a vacuum. From what we have learned of muscle fibre we can imagine the rest—how the body is drawn toward the ray or rays that have been used for effecting a grip, and how an intense and sustained pull is produced on the shell of the luckless prey when the tube-feet of one or more rays are attached to one valve and those of others to the other valve. On the ventral surface, too, situated centrally, is the mouth, and on the dorsal surface the madreporite, a calcareous plate which is a characteristic of the echinoderms, by means of which the water is admitted to the body of the animal.

It is clear that we have in the starfish an organism singularly unlike any of the others we have considered in this chapter. Of skeleton there is none of a type we generally associate with the word, yet there is a true skeleton consisting of calcareous spicules and plates, which give substance to the body and may be felt by handling the specimen. Neither is there a blood system of a kind common to the preceding types, but a circumoral vessel, with processes passing to the walls of the stomach, effects the nutrition of the body. Its nervous system is simple: brain there is none, but each ray contains a nerve cord which lies just under the skin along its whole length, divides near the mouth, and, with the branches of its fellows, forms an oral ring. The manner of respiration is not completely understood, but oxygen is certainly absorbed not only by the surface of the body, but by minute projections in the wall of the stomach and its diverticula, to which the sea-water has access.

Next we should consider a mollusc, a soft-bodied animal, usually protected by a shell, and the example that immediately suggests itself for school study is the large garden snail (*Helix aspersa*). But the molluscs have adapted themselves to widely differing conditions of life, and we cannot regard the snail as more characteristic of the mollusca than, let us say, a cuttlefish. Some of them live on land, some in fresh water, and some in the sea, and nearly all types are commonly met with. The shell of a snail is secreted by the skin, and if it is damaged the snail is able to carry out a considerable amount of repair;

examples of snails the shells of which have been broken and repaired may frequently be found. The body of the snail is fixed to the shell, which is its home and serves it as a protection against anything not strong enough to break it, but it also serves another very useful end in the case of land snails, in that it protects its occupant from death by desiccation. A damp environment is necessary for all molluscs, and the frailty of the shells of some land snails suggests the possibility that the conservation of the moisture of the body is the most useful function performed by the shell, for a weak one is no protection against insectivorous birds. Blackbirds and thrushes prey upon them and have learned how to dispose of the shell, as those who have examined their slaughter stones are well aware. The chief interest the snail provokes in a child is in its method of progression, the exact manner of which cannot easily be seen, although a snail crawling over a piece of glass, examined ventrally, is worthy of attention. It really provides a lubricated track for itself, and flows along that track by a series of muscular contractions. Its internal anatomy is well developed and indicates a high position in the scale of animal life. It possesses a pulmonary sac, into which the air is admitted by an orifice which is observable in a crawling snail as a small hole just beneath the right-hand side of the shell. All land snails resemble ‘ perfect ’ flowers in that they contain both male and female organs, and the eggs, which leave the body by a pore near the head, are fertilized before they are laid. Yet, although the same snail that produces eggs also produces sperms, cross-fertilization is effected, because, as we have learned, Nature avoids self-fertilization as a general rule, and snails pair, as do fish, birds, and mammals, by close association, each pair passing to one another the necessary male elements. The eggs are comparatively large, glistening white bodies that would speedily dry up were they not laid in damp crevices in the earth. Each garden snail may be both a father and a mother, but young snails are, nevertheless, the product of two parents, and partake of the characteristics of both.

Snails are destructive animals in cultivated plots, especially if there is in close proximity ivy or other herbage that affords them retirement and conserves moisture. But considerable observation tends to show that snails always prefer semi-decayed leaves, and do not attack robust plants if weakly or dying vegetation is available. Young snails, however, do an immense amount of damage among cultivated plants, and in a well-kept plot from which decaying leaves are removed the full-grown animals too may prove extremely destructive. It is curious that so soft a creature can destroy comparatively tough leaves, but examination of the tongue, or radula, by means of which it rasps away its food, speedily convinces the observer of its effectiveness, and no opportunity should be lost of displaying this organ under the microscope. The radula is mounted on a cushion on the floor of the mouth and is eminently suited for its purpose.

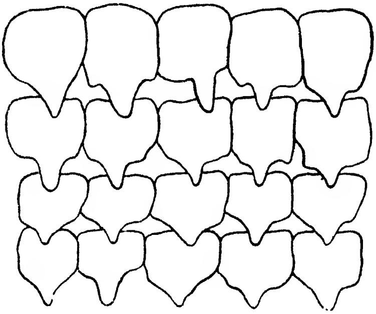


FIG. 18.—Minute portion of the radula of a snail, highly magnified.

Some aquatic and marine snails have an operculum, or cover, by means of which they can close the mouth of the shell when they have withdrawn their bodies therein, but this is not found in land snails. The well-known periwinkle (*Littorina littorea*) is a familiar example of these kinds, but there is a common pond snail (*Paludina vivipara*) that also has this protection. Land snails, however, secrete a plug formed of mucus, by means of which they close their shells in the winter or in times of drought, and this may be found in existence if snails be sought at such times.

A never-failing source of interest to children are the ‘ horns ’ of a snail. The upper ones carry eyes, but we cannot too strongly emphasize the fact that it is impossible to know what the snail sees with them, and the word eye is used in dealing with these somewhat lower animals to describe organs that are sensitive to light. The lower pair of tentacles are thought to be olfactory, but what smells they enable the snail to experience we cannot say. The nervous system is, however, a substantial, well-developed one, consisting of masses of nerve cells in different parts of the body and a larger mass, the cerebral ganglion, which probably acts as a kind of brain and co-ordinates the whole. The nerves are processes from the ganglia, as the masses are called, similarly as, it will be remembered, the rabbit's nerves are processes given off from the spinal cord. We know the snail can feel, and that it can to some extent see; we believe it can smell; but beyond this we cannot enter into its life. We have previously referred to the respiratory opening by which atmospheric air is passed to the breathing-chamber. Blood-vessels ramify through this organ and absorb oxygen, which is fixed by hæmocyanine, a substance similar to the hæmoglobin which in the blood of the rabbit it will be remembered has an affinity for oxygen. The oxygenated blood returns to the single auricle of the snail's heart, thence to the single ventricle, which divides into two aortæ that force the blood fore and aft respectively. It is clear that notwithstanding the exceedingly complex structure of the snail, as compared with a single-celled animal such as Amœba, we are dealing with an organism of a much simpler type than the rabbit.

We may now proceed to consider an animal that is, on the whole, even simpler than the snail—that very familiar and very useful creature the ordinary earthworm. It is so common that one would think it hardly needed description, yet there are few animals of which so little is known by many of us. There are forty-one different kinds of earthworm in this country, but the species with which we are most familiar is the large one (*Lumbricus terrestris*). There is, however, a large species (*Lumbricus herculeus*) which is frequently met with ; on account of its size it lends itself better to dissection, but it differs in no essential from the ordinary, though somewhat smaller, species, and we need not refer further to the distinction. It has been said that more is known about the anatomy of the frog, owing to its use as a laboratory subject, than about any other animal, but it is probable that after the frog the earthworm comes next as the animal that has been dissected most often and examined most minutely. In the worm we have an animal apparently without legs, which, nevertheless, manages to live in comparative security, notwithstanding its soft and vulnerable body, and which has, through its numerous species, adapted itself to life in almost all quarters of the globe. Except for the fact that all creatures have their utilities to contribute to the needs of the world and are, therefore, necessary, and that there cannot be degrees of necessity, we might say that the earthworm is the most necessary of all animals. Charles Darwin thought it worth a book all to itself and gave it years of patient study, and it seems desirable to refer to his *The Formation of Vegetable*

Mould through the Action of Worms, in which he proves that without earthworms there would be no crops, because the soil would become sterile and useless. The teacher is very earnestly recommended to read this volume if he has not already done so. It deals with a mass of facts and figures for which, obviously, there is no space in a book on general nature study, and it shows how painstaking and thorough original research must be if it is to lead to a definite end. But it also shows the lines along which it is possible for any ardent student of Nature to work, and must inevitably suggest directions in which research work of this type may be rewarded by the discovery of some of the many truths that Nature still withholds from us.

The earthworm appears to have no limbs, yet it is not improbable that from such a type animals possessing true limbs developed. If a worm be held in one hand while a finger of the other be rubbed along its side, a definite roughness may be detected, and this roughness is the key to an understanding of the method by which it moves. The roughness is caused by bristles, or setæ, which are embedded in pits in the sides of the animal, and there are four pairs in each of the clearly defined segments into which the body is divided, excepting only Segments 33 to 37. As the greater part of the body of the worm consists of two layers of muscle fibres, one of circular and one of longitudinal muscle, its ability to crawl slowly on any rough surface such as the earth, and to withdraw itself rapidly into its burrow, provided its ‘ tail ’ is already there, can be readily understood. The movement of a worm crawling over the ground is effected by the bristles being forced outward so as to engage in the interstices of the soil and then held there by muscular pressure. Then, the setæ in the fore-part of the body being disengaged, the circular muscles are contracted while the longitudinal ones relax, the effect being to force forward the anterior part; the action is then reversed, if we may so describe it, the anterior setæ being engaged, the hind ones released, the longitudinal muscles in the hinder part of the body contracted, and that part pulled forward toward the front part, which is held in position by the setæ. The two parts, fore and hind, move alternately, first the fore end, then the hind. The movements may be observed and understood

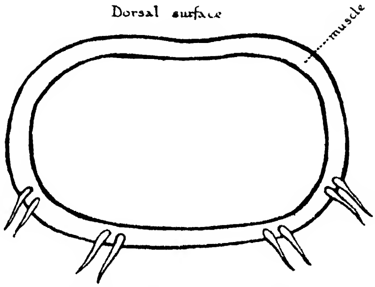


FIG. 19.—A transverse section of the body of an earthworm, showing the setæ.

once the explanation has been given, and the lesson may be driven home by displaying the helplessness of a worm placed on a piece of glass, which presents no resisting surface against which the setæ can act. Although the worm has no true feet it can walk quite well amid its normal surroundings, and we may well ask for more information as to the setæ. Are they the rudiments of limbs, *i.e.*, are they the forerunners of limbs, and have our legs and arms developed from such appendages in a long-distant past? Or are they vestigial limbs, *i.e.*, have worms lost better developed locomotive organs which their ancestors once possessed? We cannot, unfortunately, say. The former is the more attractive hypothesis, because it gives us a starting-point, but it is now acknowledged that the latter may more truly represent the facts.

It is when we inquire into the worm's manner of breathing that we find a vast difference from anything we have so far encountered in other animals. The rabbit has lungs, the fish gills, the snail a pulmonary chamber, but the worm has none of these organs. How, then, is breathing effected ? The simple process upon which in all probability the starfish depends is the clue to this mystery. It is by a very primitive but effective method. The whole of its outer surface is a lung, for it breathes by its skin. Had we time to examine some other animals, such as insects, we should find yet another manner of breathing, by means of tubes that ramify throughout the body and are known as tracheæ. They are kept open by beautiful spiral threads which strengthen them and prevent them from collapsing, and communicate with the external world by means of tiny orifices called spiracles, which can be seen without difficulty on the sides of a caterpillar with the aid of a lens. The worm, however, has managed quite well without any such arrangement, and its blood absorbs oxygen through the skin by means of hæmoglobin—not by hæmocyanine, as in the case of the snail ; in this respect, but in this only, the worm resembles the vertebrate more closely than the snail does, but even here there is an important difference in that the hæmo-

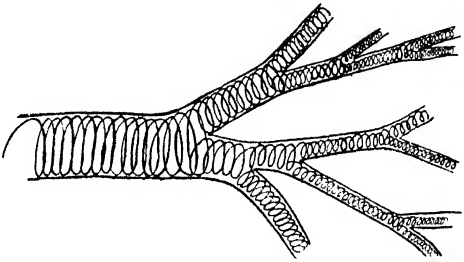


FIG. 20.—Breathing tubes of an insect, greatly enlarged.

globin in the worm is dissolved in the plasma of the blood and is not aggregated in corpuscles as in the vertebrate. In most other respects there is no important difference of structure between the worm and the snail, or, indeed, between the worm and any of the other animals we have dealt with, because the more important organs possessed by them are found also in the earthworm, or at least organs performing the same functions are. There is an alimentary canal ; a nerve cord running the whole length of the body (but, as in all invertebrate animals in which a nerve cord is found, lying beneath the digestive tract, and not above it as in all vertebrates) ; organs for producing eggs and the sperms with which to fertilize them, which, as in the snail, exist in the same individual, yet, as also in the snail, do not dispense with the necessity for pairing and the contribution of two individuals to the production of the offspring. There is in the earthworm a very important organ in the band, known as the clitellum, that may be seen encircling the body about a third of the distance from the anterior end. It must have been observed by all who have ever looked attentively at a mature earthworm, but it is sometimes erroneously supposed to be the result of a wound inflicted by a gardener's spade. Most children have been the victims of the tale that when a worm has been cut in halves the two parts come together again and join up, but that the signs of the injury are carried by the worm, as it were, to its grave !

The clitellum is really a device to provide for the protection of the eggs, and the part it plays in the reproduction of the earthworm should be explained with great care to children ; the rough outlines of the method of reproduction of the animal can be quite well explained and understood without the necessity for any dissection. We have observed that the body of the worm is divided into segments (sometimes called metameres), and the clitellum consists of Segments 33, 34, 35, 36, and 37. The mere mention of these numbers will serve to indicate to children how exact should be observation in these matters. It consists of a thickening of the tissues, but it has the capacity of producing a mucus that hardens into a horny substance serving the purpose of the shell or capsule in which the eggs of other animals are usually enclosed. On Segments 14 and 15 are the paired openings for the egress of the female and male elements respectively. Worms, as has been stated, pair, and exchange sperms for the fertilization of one another's eggs, but each worm stores the sperms it receives in a special vessel, and they do not go at once to fertilize the eggs, because the testes of the worm, which correspond to the anthers of flowers, ripen and produce their sperms before the ovaries are ripe. It is when the sperms are ready for discharge that the worms pair. When the eggs are ready to be laid the parent worm crawls backward out of the little case or cocoon that has been secreted by the clitellum, and as this presses upon the segments it squeezes out two or three of the eggs and, with them, sperms received from another worm, together with a supply of an albuminous fluid to serve as food for the young. The sperms then fuse with the eggs, which develop into young worms ; the latter feed upon the albuminous fluid and sometimes upon one another before they escape as minute youngsters and begin independent existences. The eggs of the numerous kinds of worm that live in the sea do not hatch at once into animals like their parents, but into larvæ very unlike their parents, known as trochospheres. It seems desirable to point out that as delicate organisms such as these larvæ, designed for free-swimming to aid the distribution of the species, would find no suitable conditions for life on land this stage of their development is omitted from the life-histories of terrestrial forms. The earthworm is a particularly suitable organism from which to press home the similarity of the reproductive processes of plants and animals. Each worm corresponds to a ' perfect ' flower, but needs no assistance from insects, because it can approach its neighbour, while the testes ripen before the ovaries, as do the anthers of many flowers, and the relation between sperms and pollen and eggs and ovules can be emphasized.

It will be observed that each type of animal we have considered in this chapter has taken us farther from the rabbit. Before concluding the chapter we must go a step lower to consider an even simpler animal which brings us within a reasonable distance of the simple creatures to which all too scanty reference was made in Chapter II.

We really need the microscope properly to examine our last subject, because it lives in water and it is difficult for children to use a hand-lens on it, although it is quite large enough to be seen with the naked eye. The animal in question is the freshwater polyp, or hydra, of which two species are found commonly in the waters of this country. But we shall in passing be able to make reference to their close relatives, the jellyfish, so familiar to residents on some parts of our coasts, for these latter animals, strangely different though they appear, are really very similar in many respects.

If some plants be taken from a stream and placed in a bowl of clear water a number of small protuberances of a green or brown colour may be seen adhering to the stalks. The experienced naturalist will soon learn to detect them and to decide very quickly whether specimens are present in any particular bunch of weed. It is really desirable that they should be seen, and the enthusiastic teacher will not be satisfied unless he has shown his class a fully extended hydra under the low power of a microscope. Fortunately, however, a great deal may be seen by placing the leaf or small piece of stalk to which the animal is attached on a glass slide with a generous drop of water and examining it with a hand-lens, and thereby, at least, its general shape can be observed. Since the phylum to which it belongs contains the animals semi-popularly known as zoophytes, it seems unreasonable to object to the statement that it looks more like a plant than an animal, but it is sufficiently high in the scale to enable us to say definitely that it is an animal, though we are not likely to be fortunate enough to see how it feeds. We shall see that it is a stalk-like creature fixed to its support at one pole and that the other carries a number of free-moving arms, six or eight in number, that move slowly about like small worms ; and that is all that can be seen with an ordinary lens. But if we use the low power of a microscope we shall see all this much more clearly, and by increasing the power and the amount of careful observation we shall see a great deal more than this, and may quite likely be able to make out something of the structure of the body of the hydra. Ordinarily, however, this cannot be seen without killing and staining it.

Now the animal we are observing is not unlike the sea anemone, an animal that many children have seen and all have heard of. It is fixed by its base to a comparatively firm support, it has a mouth surrounded by tentacles, and a stomach like the stomachs of the people for whom a certain patent medicine is provided—" a simple sack or bag into which the food falls." Our hydra has not the number of tentacles that the sea anemone has, but for its size they are larger, and no less deadly to their prey. It is a really simple animal, for its body consists of only two layers of cells surrounding a cavity that contains no organs whatever. Nevertheless, the inner layer of cells possesses the power of digesting food taken in by the mouth, and of absorbing its nutritive matter ; and the absorbent surface is a very large one, the body cavity extending into the arms or tentacles and into any ‘ buds ’ the hydra may bear, for it produces buds very much like the side shoots of plants. Unlike those side shoots, however, the buds of the hydra may one day detach themselves and become real hydræ like their parent. Hydræ with buds are quite commonly found, and often some bear swellings which indicate that processes are being carried on whereby new hydræ will be produced in a manner more usual in nature than the system of multiplication by budding. The swellings indicate where male and female ‘ germs ’ are being produced, for the hydra can reproduce itself both by means of buds, as plants may be propagated by cuttings, and by eggs that are fertilized in the same way as the seeds of plants.

As we examine the hydra it looks a harmless little animal, very helpless and pitiable. In reality it is a relentless devastator of the small life of the water, a terror comparable to the mythical Hydra of the classics, “ a strange monster with a hundred heads.” It possesses batteries which are capable, in its own little world, of results as great as those of the submerged torpedo tubes of the Dardanelles forts. Those feeble-looking arms are withdrawn into the body whenever the glass slide is shaken or the water agitated, and when the animal is resting or digesting its food, but at other times they are spread wide, ready for their prey, which consists of the small crustacea of the fresh waters, little river worms, and probably the aquatic larvæ of minute insects. When such objects come within reach of the tentacles numerous tiny stinging threads are shot out toward them, paralysing them, depriving them of all power of resistance, and reducing them to a state of impotence in which they can be ingested. Unfortunately, but as is to be expected in so small an animal as the hydra, these threads can only be seen with the aid of the comparatively high powers of the microscope, and their action cannot be demonstrated in the conditions existing in class, but it can be explained, and the explanation can be made more effective by means of blackboard drawings that will not be beyond the capabilities of any teacher. If we could see them as they are seen when the hydra is macerated and examined cell by cell, we should find that some of the cells of the outer layer of the arms contain, embedded in them, clear, egg-shaped bodies, which are called stinging capsules, or, properly, nematocysts. These bodies are amazingly designed, and because they are met with in such simple animals we may well be tempted to think that they are more wonderful than some of the organs of higher creatures with which we are more familiar. If, however, we ever are so tempted we can always consider again for a few moments the nervous system of a rabbit ; a very little consideration will serve to convince us that in none of these lower animals is there a piece of matter so wonderful as any morsel of a rabbit's brain. Still, these nematocysts are quite sufficiently wonderful to justify the most careful attention, and the writer has found by experience that their description readily grips and holds the attention of children. The capsules at their ' business end ' have invaginated into them a hollow process the exact nature of which it is somewhat difficult to explain even by illustration, but it can be demonstrated by taking a football cover, lacing it up, forcing one half into the other, and then bringing the edges as near together as possible. Children will then understand quite readily that if air could be forced rapidly into the empty cover the internal fold would be pushed outward with some force. Now suppose that a string were fastened to the centre of the invaginated part of the cover ; the force with which it was projected would throw it out into the air. This is a rough indication of the manner in which the nematocyst functions. As a matter of fact, the stinging thread is a hollow continuation of the interior of the capsule, an arrangement permitting more effective and rapid action. But this is not all. The nematocyst is embedded in a cell called a cnidoblast which is itself embedded in one of the larger surface cells, and at its surface the cnidoblast is furnished with a very fine process which is called a trigger-hair, or, properly, though children should not be bothered and frightened by such names, a cnidocil. This is the sensitive point, a trigger indeed, for it is when the victim touches this that the whole cell suddenly contracts, forcing outward the inside fold of the stinging capsule with its long thread, which seals the doom of any minute animal coming into contact with it.

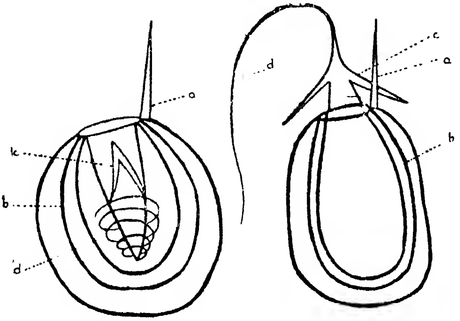


FIG. 21.—A Cnidoblast of Hydra, much magnified: left, unexploded; right, exploded. (*a*) Cnidocil. (*b*) Nematocyst. (*c*) Barbs. (*d*) Stinging thread.

The species of hydra commonly found in our waters are the green (*Hydra viridis*), and the brown (*Hydra fusca* or *Hydra vulgaris*). The latter is probably the commoner, taking the country as a whole, but the writer has certainly found the green hydra more common in the districts he has explored. The brown hydra is the more graceful, because it is long in the body, and its tentacles are more attenuated than those of its green relative, but it lacks the rich green colour. As has been remarked, hydræ propagate their kind by budding and by the production of male and female cells which coalesce into fertile eggs, but they also possess the power of successfully emerging from such simple surgical operations as complete division, and a very small piece of a hydra will grow into a complete animal with tentacles and stinging threads. The power of surviving mutilation is possessed by many animals that are not built up of a number of specialized and localized organs. Hydræ are able to shift their habitat by detaching themselves from the base to which they are affixed and by progressing downstream with the current. They will attach themselves to moving objects, but they can progress, very slowly of course, by sinking to the bottom and adopting an action similar in appearance to that of the ‘ looper ’ caterpillar of a geometer moth.

Hydra is a simple representative of a phylum that presents many diverse forms, all of which possess a great deal in common or indicate at some stage of their life-histories an undoubted relationship one to another. Some of them develop from the egg and maintain their individuality through life, as Hydra, but even Hydra develops buds that produce tentacles, and while these remain attached to the parent plant they must be regarded as turning the whole organism into a colony. Some types, such as Obelia, adopt the colonial form as normal, and suggest a branch of a plant ; some of the buds are specialized as reproductive organs, and are known as medusa-buds, because they produce small jellyfish. These jellyfish, however, are not the larval forms of colonies to be, but an alternate generation destined to produce sperms and ova in separate individuals, which develop into larvæ from which new colonial forms grow. We shall consider the subjects of alternation of generation and metamorphosis in Chapter XI. Some of the relatives of Hydra have only a jellyfish form, and many, again, much larger and more complicated in structure, never pass through a jellyfish stage. We can only refer to these cases in passing, but they may be followed up with profit, and those who have access to the sea will find many opportunities of utilizing such subjects as Obelia and Anemone.

CHAPTER X

THE ORIGIN OF LIFE

WE commented in Chapter I upon the fact that we do not know what life is, and that we have so far succeeded in getting no farther than to examine the manner in which living processes are manifested. Because, however, we know nothing of the origin of life we need not be unduly diffident in approaching the subject. There was a time when to attempt to probe the mystery of the origin of life on the earth was regarded as impious, and it is true that there exist even to-day a considerable number of people who regard the Biblical story of creation as a revelation to be literally accepted in all its details. Not to march in step with these does not commit us to a declaration that the Book of Genesis is not inspired, or that it does not constitute a document acceptable to a revealed religion.

Natural law was created for the good ordering of the world, but the Power that created the law is not bound by it, and it can be suspended. On the occasions when it is suspended, or when, owing to our lack of knowledge, it seems to us to be suspended, we speak of miracles, because being ourselves bound by natural law we have no explanation to give of what we do not understand. But we must bear in mind that, as the operation of natural law becomes better understood, a number of phenomena for which we had no explanation in the past cease to be regarded as miracles, and the belief that " the age of miracles is past " grows. We know that the earth plays a part in the solar system, and it may be that the solar system plays a similar part in the universe; life plays its part on the earth in obedience to natural law which is ordinarily unalterable. Therefore, although it is a seductive attraction, we must be constantly on our guard against the assumption that anything we cannot understand is the result of a miracle. But so far as the origin of life on the earth is concerned, we are as much in the dark as ever and seem to have only one alternative to regarding it as a miracle, namely, to suppose it was an accident—that the chemical processes in which life can be manifested by sheer accident came to be aggregated in such a manner that, given the right amount of heat and, probably, light, life was spontaneously generated.

When, however, we begin to examine such a theory, or indeed any other theory that has been advanced, we are faced with many difficulties, each of which can be overcome only by the adoption of an assumption at least as great as that " God's in His heaven, All's right with the world," and that an Omnipotent Power created life. A number of theories as to the origin of life have been put forward, and in very recent years claims have been made to the effect that certain substances when combined produce bodies that have exhibited some of the phenomena associated with living processes. But since we cannot examine these claims in a treatise that attempts only to deal with life as it is manifested and not with speculative theology, we shall find room in this chapter only for observations that may help the teacher to appreciate the opacity of the mystery in which this great question is at present wrapped, and to ponder on certain considerations that have to be taken into account in seeking explanations.

Until the seventeenth century it had not seriously been doubted that living organisms are spontaneously generated from non-living matter. It was not till the nineteenth century that, largely owing to the work of Pasteur and Tyndall, the theory of biogenesis—that living matter is produced only by living matter—became firmly established. It should be understood that the acceptance of the doctrine of biogenesis does not rule out recognition of the possibility that originally living organisms may have been evolved from non-living material, or that unknown to us—possibly in the depths of the sea or in tropical swamps—the evolution of living forms may even now be taking place. It is quite certain, however, that no evidence exists to show that life has ever been produced except from life.

Circumstances have from time to time lent colour to the doctrine of abiogenesis, as belief in the spontaneous generation of living forms is called. Gelatinous matter dredged up from the depths of the sea was at one time alleged to represent the substance in which life was from time to time implanted in consequence of chemical changes, which in due course produced just those conditions in which life became possible—perhaps inevitable, whenever the exact condition was attained. Subsequently, however, it was demonstrated that this deep-sea slime was not what has been described as an upward or constructive stage in the evolution of life, but a downward, destructive stage, for it was shown that it really represented the *débris* of the soft parts of myriads of animals that had been, which had sunk to the bottom of the sea, where it was preserved by the carbonic acid in the water. The question is whether the substance, to which the name bathybius (from the Greek βαθύς, deep, and βίος, life) was given, is of organic origin at all. One theory, held by Huxley, is that it is merely calcium sulphate which has been precipitated from sea-water through the agency of alcohol. When Amœba was discovered it was thought again that Nature had been caught, as it were, in the act of producing the living substance from the non-living.

Subsequent investigation proved that any individual amœba had been, ever since it had an independent existence, a living organism, and that it had been produced from a living organism like itself, not from a speck of inorganic matter suddenly endowed with life. Amœba must at present be regarded as the simplest form of animal life, but we are not permitted to regard it as representing in any sense the beginning of life on the earth, because there must have been in existence a supply of food-plants, even though they were only single-celled plants, before the advent of such an animal. Moreover, it cannot be too clearly understood that simple though it be in that it is unicellular, possessing no differentiated tissue, from a physiological point of view Amœba is very complex, and cannot be assumed necessarily to bear any resemblance to the first organism that was indubitably an animal.

Unless we suppose—and there is no scientific objection to such an hypothesis—that a primitive type of protoplasm, fortuitously formed and capable of absorbing and assimilating simple non-organic matter, preceded and ultimately gave rise to plants and animals, we are forced to think that before any living organisms came into existence there must have been a supply of suitable food material. One of the characteristics of life is, we observed quite early, its continuity, its power of reproducing itself. A living organism consists of certain chemical substances,[1] and its continuity as a species or as a modification of that species in time is dependent upon there being a supply of such substances always available, means of breaking down the combinations in which they exist, and opportunity for their dispersal. Complex as are the operations by means of which the cycle of life is maintained, they appear simple compared with the process, whatever it was, by which life was introduced. Perhaps by way of introduction to a consideration of the subject we may briefly outline this cycle of life.

---

[1] See Chapter I.

We have seen that the rabbit has a digestive system capable of making use of just those substances of which its own body is built up—protoplasm, which consists mainly of the elements carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. Together with the oxygen contained in the air the rabbit's diet provides it with all it needs for its vital processes, and except that some animals obtain their free oxygen from water instead of from air the statement is true of all animals. All living matter consists of protoplasm, and all animals live upon living matter or matter that has lived. Plants, we know, are different in this respect, though we must except the fungi and bacteria, which resemble animals in that they must have their food elaborated for them. All green plants feed upon simple inorganic matter, and obtain their carbon from the carbon dioxide in the air by a process that has earned for them the reputation of being the most economical food factories that exist. We do not need to repeat the details of plant nutrition with which we dealt in Chapter III, but it is necessary to point out that the simple substances upon which plants draw are largely the products of animals which, while alive, breathe out carbon dioxide and in both their lives and their deaths strew the earth with substances that are also brought to account by plants. Plants themselves provide substances for their descendants when they die, for their bodies also decompose and are broken down in the same way that the bodies of animals are. The work of breaking down is performed by bacteria, but so far as the recovery of the nitrogen is concerned the conversion of dead organic substances into plant food is not a simple process, and many different kinds of bacteria take part in it.

We are all familiar with the signs of decay in a dead animal or plant, and that putrefaction is the result of the action of ‘ germs ’ is now generally appreciated. Putrefactive bacteria break down the dead substances and simplify them, and ammonia compounds are produced from the proteins. Other groups of bacteria are instrumental in converting the ammonia compounds into nitrites, and yet others complete the process by changing the nitrites into nitrates, in which form, as we know, they can be made use of by plants. Except for the power possessed by certain soil bacteria of fixing nitrogen derived directly from the air, this is the only source of nitrogen available to plants. It is interesting to note that forms of amœba live in soil and prey upon bacteria, and it is recognized that the control of the multiplication of these amœbæ is one of the most important problems upon which agricultural research can at present engage.

Although animals of one kind subsist upon animals of another kind, we find that ultimately all animals are dependent upon plants, without which animal life would come to an end. Without green plants animals would for a time be able to eat one another, but every death would mean the loss of so much material that is in existing circumstances retained in circulation by the ability of plants to utilize the products of decomposition.

This may appear to have little bearing upon the origin of life, but since the subject is bound up with that of the means of subsistence we must regard the question from the point of view of food. Because animals cannot live upon simple inorganic substances there appears to be no alternative to the assumption that before animals appeared there must have been in existence complex organic bodies that could be used by them as food, *i.e.*, plants ; and if green plants alone possess the power of living on elemental substances we seem forced to the conclusion that the development of chlorophyll made organic life on the earth possible—that is, that life was first manifested in the form of a green plant.

We observed that some forms of bacteria are able to fix nitrogen derived from its free state in the air. If they are able to do this may they not be able in like manner to collect carbon similarly derived? Some bacteria are alleged to be able to obtain carbon from the carbon dioxide in the air, but this is still disputed, and we know that bacteria in general possess no such power. Chemists have, however, succeeded in building up sugar from inorganic materials, and should investigation along the path thus opened lead to more positive information it may be found that a nearer approach has been obtained to the great question of the origin of life. But even so we must guard against too readily accepting such evidence in coming to conclusions as to the forms in which life was first implanted. Bacteria, primitive though they be, have in process of time undergone many changes such as would be necessitated by altered conditions—at least, there seems little reason to suppose that they alone in the organic world have been passed over unchanged by time. Although such investigations may lead us ultimately to a shrewd speculation as to the manner in which living organisms were evolved from the inanimate world, it would seem that the original implantation of life goes back to a time when in every respect conditions on the earth were so different from those existing to-day that they would have been possible to no known type of organism.

There seem, therefore, but two hypotheses from which we can approach the question of the origin of life on the earth. We may assume that conditions existing when life first made its appearance were in every respect different from those existing now, when the living organisms of the period were able to secure the necessities of existence in a way in which no such organism can glean them to-day; and we may even assume that life was manifested in a setting that contained none, or only some, of the chemical elements as we know them. If we accept this it must be admitted that further consideration is useless, because we should be dealing with a set of conditions of which we not only know nothing, but in all probability are incapable of knowing anything. The other hypothesis is that when life first made its appearance conditions, although necessarily differing widely from those of to-day, conformed to existing chemical and physical conditions in most particulars, and in this case we appear to be forced to the conclusion that life must have appeared first in the form of green plants, which alone possess capabilities for an existence independent of animals and other plants, and that animals and non-green plants, including bacteria, were evolved from these. This, however, it must be admitted, is arguing in a circle, so far as the solution of the question of the manner in which life was originated is concerned, because chlorophyll cannot at present be produced otherwise than through the green plant—that is, it can be produced only by organisms that already possess it. If we have reached any definite point in our inquiry, assuming our premises to be on the right lines, we are forced to the conclusion that an investigation into the origin of life is an investigation into the origin of chlorophyll.

The evolution of animal life from plant life, as will be readily understood by those who have learned the lesson of *Euglena viridis*,[1] is a matter of considerable simplicity compared with the question of the origin of life itself, or, as has been suggested, the quest for the first piece of chlorophyll.

---

[1] See Chapter II.

CHAPTER XI

METAMORPHOSIS AND ALTERNATION

MOST children and some adults know that the crawling, worm-like caterpillar and the aquatic, limbless tadpole are destined to become respectively a gorgeous flying butterfly or moth, and a four-legged, mainly land-dwelling frog; but it is not generally realized that such changes, known as metamorphoses, are not unusual in the animal world and are, indeed, usual in the plant world. Still less is the phenomenon of alternation of generations understood, neither is it realized that it is common to a very large number of animals and plants. An attempt will be made to sketch rapidly the life-histories of a number of organisms that exhibit these phenomena, and this may lead to a consideration of the ends attained thereby.

The eggs of the common frog, as has been stated in Chapter VII, are laid in stagnant water, and although they at first rest on the bottom they rapidly absorb water, swell, and rise to the surface. The rapidity with which they develop depends upon the temperature, and a period of warm weather will expedite considerably the appearance of the young tadpoles, but they generally emerge from their eggs about three weeks after these are laid. It would be a mistake to describe the stages through which the frog passes as those of egg, tadpole, and frog, and to do so would lead to the overlooking of changes that can, fortunately, be watched in every school in which nature study is taught. When first hatched the little animal is dependent upon its skin for its absorption of oxygen; as was mentioned when we were considering the earthworm, this is not an unusual method of respiration, and for a time it suits the animal admirably. Its digestive arrangements, too, are in a primitive condition, and consist of the greater part of the body cavity used as a receptacle for the remains of the mass of yolk with which the egg when originally laid was packed. There is no functional mouth, and the yolk continues to be absorbed and to build up the body, as the food stored in a seed or an egg nourishes any other organism before it can tap exterior resources. There are no eyes or other organs, so far as can be seen, to enable the living animal to bridge the gulf between itself and the non-living world. But in less than a week the sucker-like orifice that has allowed the semi-embryonic animal to attach itself by its fore-end to stones and weeds becomes changed into a mouth furnished at first with lips and, very shortly afterward, with a beak capable of breaking up organic matter such as small water plants. Further changes make their appearance at this time: eyes develop, the head becomes distinct from the body, and tufts of gills appear which serve more effectually than the skin in performing that exchange of gases that constitutes breathing, though it should be explained that throughout the life of a frog cutaneous breathing augments the supply of oxygen obtained by gills or lungs. Change is the order of the day, however, and very soon—in three or four days—the gills are absorbed, and a fresh set of a more elaborate character form in chambers behind the head. During this time further changes have been in progress, for a long alimentary canal has been formed now that the egg-substance has been built up into the body of the tadpole, and the tail becomes larger and more efficient as a swimming organ. Although its food is mainly vegetable (tadpoles are more effective even than water snails in clearing the confervæ from the glass of an aquarium) it is

XII. A TOAD (*Bufo vulgaris*) 198

The toad may be distinguished from the frog by the possession of a warty skin

Photo E. W. Royston

really omnivorous, and, in addition to such animal prey as comes its way when it is investigating the possibilities of water plants, a tadpole does not hesitate to attack its fellows and to devour them ; a number of tadpoles confined in a receptacle that contains no food for them fall upon one another until only one survives, probably with a very imperfect tail, because its owner has in turn been partially eaten by a fellow which it has since completely devoured.

Well on in the summer—the exact time varies with the quantity of food available—a greater, but still a gradual, change commences. The gills are slowly absorbed, and organs that have formed behind them to take their place open out as lungs capable of making use of the oxygen in the air. For a time the young frog can breathe either by gills or lungs, and uses both, coming to the surface of the water to gulp in air ; if access to the surface is denied it by stretching a piece of muslin below the surface, the period of gill breathing can be prolonged while other modifications progress. Teeth have developed, and tubercles appear, first on each side of the posterior end of the body, then at the anterior. As these push out and develop into limbs the tail is gradually absorbed, and in due course the young frog makes its appearance on land, where it feeds upon insects and such other small animals as do not avoid it successfully, until the cooler atmosphere of autumn causes it to seek winter quarters in a hole in a bank.

The appearance and habits of tadpoles are now so familiar to most people that no attempt at a detailed description has been made. Anyone who watches them in a pond or an aquarium will in ten minutes acquire a fairly clear conception of their appearance and manner of swimming and feeding. The purpose of these paragraphs is to indicate to teachers and others the changes that may be witnessed by those who wish to follow the life-history through. It is important to observe that at no stage does the tadpole cast off anything it has developed; the original gills are absorbed into the organism whence they came when the second gills appear, the second gills when the lungs begin to function, the tail when the limbs are formed, the horny beak when the gap widens and teeth are developed. Other changes, equally important but less obvious, have been in progress, affecting not only the internal organs, but the muscles and blood-vessels, but they are observed with difficulty and mean less to those who are studying the subject amid the limitations inevitable in most schools and with young children.

Although such a life-history cannot readily be found among the plants which we encounter in our gardens and during our daily walks, we now know that metamorphoses quite as remarkable take place among plants, though it seems that such life-histories have been retained only by certain plants that have continued to live in primitive conditions and have not adapted themselves to a very different habitat from that in which they attained a form and structure from which they have not materially altered. Such plants live in water—ponds and the sea—and we shall consider now a genus called Ulothrix, the members of which are grouped with Protococcus among the algæ. Ulothrix is a common filamentous plant, consisting of algal cells, detached examples of which may often be found on the shore between the tides. We shall not expect the production of flowers in such a plant—we have already remarked that it exhibits primitive characteristics—and we shall be breaking new ground in dealing with those processes by which it multiplies and distributes its offspring. By cell division it grows until it has attained maturity and until the conditions of its surroundings are propitious, when some of the cells of which it is composed begin to divide in a manner different from that by which increase of size—mere vegetative growth—is attained. The protoplasm of the cells in question divides into a number of bodies which emerge from the original cell wall and enter the surrounding water. These bodies, as may be readily appreciated by those who have been able to judge of the size of the original cell by examination of a filament of Ulothrix under a microscope, are extremely minute, and cannot be seen by the unassisted eye, but they each possess four little whip-like threads at the narrower end of their bodies, and by the constant lashing of these threads they are driven through the water. Now these very motile little organisms bear a most remarkable resemblance to members of a group of primitive creatures known as flagellates that are generally regarded as animals. They feed like animals, though some of them possess chlorophyll that aids in their nutrition, but they never grow up into any other form. These little plants, however, have before them a very different future, more different even than tadpoles have before them. We can hardly imagine anything more different from the fixed mother plant than these active little creatures, swimming freely in the water and travelling comparatively long distances from her. But this form is only an early phase in the life-history of Ulothrix. A time comes when the free-swimming organisms settle upon a solid foundation such as a rock, when each develops a new cell wall and a base by which it attaches itself to its foundation, and then sends forth a filament like that from which it sprang. This life-history is quite as remarkable as that of the frog—perhaps more so, because the larval form exhibits a capacity for an amount of movement that we are accustomed to associate with an animal rather than a plant. However, the possession of flagella and power of movement is so frequently encountered among simple plants that we must content ourselves with contrasting the differences between the free-swimming larvæ and the mature Ulothrix.

Metamorphosis and alternation of generations are sometimes confounded, and in order that the position might be made quite clear we have just considered a plant that might be said to a certain extent to exhibit both phenomena. The life-history of Ulothrix we have examined is a definite case of metamorphosis. We related that the protoplasm of a cell breaks up into motile organisms, called zooids, which swim away from their parent plant and after a time settle down in their free-swimming stage and commence a vegetative existence in which they develop into plant forms; as such they in time produce propagative cells that develop again into free-swimming zooids. Sometimes a cell of the mother plant divides into a much greater number of smaller cells, which may be distinguished from the zooids by their possessing only two flagella each instead of four. When such cells meet similar ones from another plant of Ulothrix they conjugate in pairs, each pair becoming a single cell, which loses its flagella and then settles down for a period of rest; after this its cell wall ruptures, and the contents emerge as four bodies, each of which may settle down as the simpler zooids did and grow into a plant like that from which the conjugating cells originated. These phenomena hardly constitute a case of alternation of generations, but they are in the nature of it; there are some sexual and some asexual generations, which do not, however, alternate. In Chapter XVI we shall have something to say about the life-history of the bracken fern (*Pteridium aquilinum*), in which a true alternation of generations may be easily followed.

Having considered at some length the metamorphosis of the frog, we shall not proceed to a detailed account of the life-histories of insects such as butterflies and moths, because they are widely known. The insects exhibit every imaginable type of life-history, and to most species metamorphosis in varying degrees is the rule ; in some it is absent, the egg and the perfect insect representing the only stages through which they pass. But between this and the full metamorphosis of a moth, for instance, there are many modifications round a type such as a cockroach, in which the product of the egg passes through a change in which it imperceptibly assumes the form of the mature insect, whose sole aim is to mate and maintain the race. Many insects, however, are examples of alternation of generation and have received much less general study. We will describe briefly the life-history of a very common insect which presents interesting features.

The aphides or plant-lice are always and everywhere with us, and it is not necessary to go into the country to find them. They may be discovered on the leaves and stalks of plants growing in the most congested parts of Southwark, and a considerable proportion of the lettuces offered for sale in the summer are doubtless infested with the green aphides. There are many species, but the life-history is very similar in each case. The eggs, which are produced in autumn, withstand the winter and hatch in the spring as soon as the warmth is sufficient to bring forth spring foliage, little green insects emerging. This stage is well known to gardeners and to the preparers of salads, who have difficulty in dislodging them from the leaves and stems to which they adhere. They feed upon the sap of the plant, which they imbibe through a beak consisting of a grooved sheath called the labium, which encloses the sharp, pointed mandibles and maxillæ. These latter mouth-parts pierce the leaf, and the juices are sucked up through the labium. The process of feeding is more or less continuous, and as they grow the aphides moult their skins several times, but do not undergo any important change in form. After feeding for about fifteen days they are capable of laying eggs. The remarkable things to observe are that the eggs, though produced without the assistance of other aphides or of any kind of pairing, are fertile, and that they hatch within the body of the parent, the young being born ' alive ' and active. It has always seemed to the writer that this parthenogenesis offers tremendous opportunity to the teacher or parent who is willing to take advantage of it in conveying preliminary information to children regarding the facts of life. It should be observed that such a stage in the life-histories of living things is exceedingly rare, but is met with more frequently among insects than among the members of any other group. Brood after brood of these modified females, for so they must be regarded, is produced throughout the spring and summer, each brood maturing (in a fortnight from its own appearance on the scene) and producing its progeny, which in turn produce others. It may well be understood that increase is at an enormous rate—indeed, were it not for the checks Nature has imposed in the form of lace-wings, hover flies, and ladybirds, plant life might easily be exterminated by their activities. It should be brought to the notice of advocates of the formation of sparrow clubs that the house-sparrow (*Passer domesticus*) is one of the most valuable allies the gardener has in his war with green aphides. The sparrow is an omnivorous feeder itself, but like most omnivorous birds finds that animal food suits its young best. During the whole of the spring and summer, when sparrows are producing nest after nest of young, the parents may be seen gathering green aphides from the plants and taking them to their nests. Annoying though it is to find one's early peas bitten off by sparrows, who as a rule ask only for the water the succulent young pea-shoots contain and will leave the peas alone if they have direct access to water, it needs no imagination to understand that during this period the sparrows more than pay for their keep during the rest of the year. Sparrow clubs only upset the balance that Nature always provides when she is left to herself, and are the greatest friends the aphides have.

But later on in the season the broods of aphides produced may be observed to differ from their virgin parents ; swarms of winged females appear. These are not, however, essentially different from the earlier forms, and it seems that they are produced when the wingless broods are beginning to press upon the sources of food to which they have access—sources that are limited owing to the immobility of the wingless insects ; the new broods are provided with the means of emigrating, and they seek and find pastures new. Broods of females of these types, some winged, some wingless, continue to be produced until the autumn forms appear which exhibit sexual differentiation and develop into wingless males and females ; these pair, the females producing eggs, which they deposit on twigs and dry leaves. And so the life-history is completed. These males and females give rise to numerous generations of females, which reproduce themselves without the intervention of males ; there is, in fact, one sexual generation followed by a varying number of asexual generations. We shall see when we consider the bracken fern that a somewhat similar life-history is worked out in this plant ; but there is only one sexless generation instead of many, the many in the case of the aphides being due to the necessities that do not arise in the case of a plant that has developed other means of ensuring its distribution and its hold of its place in the world.

It has been supposed that the explanation of metamorphosis and alternation of generations might be found in the probability that every individual organism in its development from the simple cell recapitulates the history of its race, but more recent thought has discredited this view. It was a picturesque theory, the supposition that the worm-like caterpillar or maggot represented a type in evolution that had been characteristic of insects of a certain period. Those who accept the annelidan theory, that evolution progressed along lines that ultimately produced worms, and that all the higher groups of animals were evolved from worms, would find much to attract them in such a conception; but it is now generally thought that the larval forms of living things have been the subjects of modifications resulting from environment, as undoubtedly have the more mature forms into which they grow. The greater facilities that have existed in recent times have enabled investigators to conclude that the metamorphosis of a butterfly is merely a system of growth, and that the changes from larva to chrysalis and from chrysalis to imago are not so sudden as they appear to be, for the groups of cells from which the specialized organs of the mature insect, such as the wings, develop may now be shown to exist in the caterpillar. Children should be given the opportunity of watching these changes, and if some nettles populated with full-fed larvæ of the peacock butterfly (*Vanessa Io*) are successfully gathered the teacher may be content that the best possible example has been secured. But, owing to the vascular nature of nettles, it is well to make certain that the caterpillars are full-fed; nettles quickly dry up, even when placed immediately in water, and if the insects need to continue to feed they will at once desert their hardening food and gallop off at a pace that makes locating them impossible. There is no outward sign of the change that is about to take place in the full-fed insect. Each time it has changed its skin—that is, cast off the chitinous cuticle which is almost characteristic of insects—it has resembled its preceding form in all but size. But having reached its allotted span of life as a caterpillar it spins a tiny pad of silk, to which it adheres mainly by means of its hindmost pair of ambulatory 'legs,' hanging head downward; in this position it sheds its last larval skin, a spiny process in the form of a hook now engaging in the silken pad, which, by the way, represents the cocoon of moths such as the silkworm. What a transformation! This ecdysis results not in a larger caterpillar, but in a chrysalis or pupa that is unlike either the caterpillar or the butterfly into which it is destined to change. Yet close examination will indicate that the butterfly is very clearly there, and its antennæ, legs, and wings are manifestly enclosed within the normally inactive case. The abdomen can be seen to be that of a butterfly, and the parts of the chrysalis are more obviously differentiated than were the parts of the larva. A resting period ensues, and there emerges from the dry case a fly-like insect with long legs and very crumpled and apparently useless wings; the latter unfold while the observer stands by, dry, and harden, and the peacock butterfly is on the wing, surely one of the most beautiful and graceful things created. The change has been one of slow growth and not of catastrophic mutation such as the rapid transformation from caterpillar to chrysalis and chrysalis to butterfly suggest; the changes have been masked by the cuticles, which have not themselves changed, being of non-living material. The development of the butterfly has often been used as a symbol of the resurrection, and, when it was demonstrated that the changes were more gradual than was supposed by the earlier naturalists, it was felt by many that the simile had been lost. But those who look below the surface, believing that life in this world has been given us for the gradual formation of character to the end that ultimately we may reach a higher sphere, will prefer to see in the metamorphoses of beautiful insects an even more perfect type wherewith to illustrate their faith; and for them those small groups of cells that exist in the crawling caterpillar or maggot, the imaginal disks, whence develop the characteristic organs of the perfect insect, become symbols of the virtues that are given each of us to feed and strengthen into character that shall fit more appropriately a higher state. "The caterpillar crawling over the leaf . . . may be regarded as a creature preparing for a change to the true conditions of its life. . . . But the light which research has thrown on the nature of these wonderful life-histories, the demonstration of the unseen presence of growth within the insect, confirm surely the intuition of the old-time students, who saw in these changes, so familiar and yet so wonderful, a parable and a prophecy of the higher nature of man."[1]

Metamorphosis in development, especially of animals, is much more common than is generally supposed by those who have not given special attention to the subject, and the teacher should not fail to make this fact clear to his class. During part of their pre-natal development mammals, including ourselves, possess gill-slits, from which it has been inferred that they are descended from gill-breathing animals, *i.e.*, animals that obtained their supply of oxygen from the water, or from land animals that had water-breathing larvæ. Certain it is that larval forms are common to a very large number of animals, and in many cases the larval forms are much more motile than the mature forms. It has been thought that the larval forms represent the highest stage in evolution that animals had attained at some particular period in time, and that development has proceeded from such forms along different lines. Marine worms possess a larval stage resembling very closely a stage through which many marine molluscs pass. Now these two groups of animals in their maturity exhibit widely differing characteristics, but we are forced to consider the possibility that both may have sprung from one type which passed through a larval stage, and that environment has not acted so strongly on the larval animal as it has on the mature forms which adopted different manners of life. We can see the advantages that may accrue to an animal or plant that is able to divide its life up into two or more parts to which different activities are allotted. The caterpillar or maggot is specially suited for what we may call a vegetative life, devoted to feeding and the storage of nutriment. But it is not well suited to conditions demanding courtship, marriage, and the propagation and distribution of its kind, for which wings stand it in good stead. Some organisms, on the other hand, find a relatively immobile condition suitable for the propagation of young which possess actively motile powers sufficient to ensure their distribution, as we have seen in the case of Ulothrix and should see, if we examined their life-histories, among such forms as jellyfish, snails, worms, and starfish.

---

[1] G. H. Carpenter, *The Life-Story of Insects.*

CHAPTER XII

SPONGING—AND CO-OPERATION

IN the earlier pages we considered briefly the fungus that in co-operation with algæ establishes a very satisfactory give-and-take amalgamation which leads to a *modus vivendi* by which each benefits from the association, making use of the efforts of the other and giving services in return. We have also considered the position of the mistletoe in relation to its host, and the ivy. We might have referred to similar associations between animals and between animals and plants. It is rather difficult sometimes to draw a line between one association and another and to say whether one species is sponging on the other—*i.e.*, is parasitic—or whether it is an association for mutual benefit. In ordinary practice we say that once species is parasitic on another when it derives an advantage from the association greater than it gives to the other, or when the disadvantages suffered by the other outweigh the advantages that accrue to it. It is probable that some advantages are always obtained, even by the victim, as an outcome of these associations, but in a great many of the more obvious instances with which we are commonly acquainted the victims would be more than willing to be free of the uninvited guest ; it need only be mentioned that malaria, which is becoming common in England again, and diseases due to the poisons produced by infestation by certain bacteria, are all the results of parasitism which illustrate this side of the question.

Yet parasitism is not, regarded broadly, an unmitigated evil. We have before stated that Nature cares nothing for the individual, but everything for the race. We observed that birds prey upon insects and so keep them in check, with the result that insects which prey upon plants, and therefore on us by devouring our food-supply, are kept under control. These, of course, are not cases of parasitism proper, but they serve to indicate the action of one organism on another. One of the most interesting cases of parasitism is that of the ichneumon fly, which by means of its sting or ovipositor implants its eggs in the bodies of caterpillars. The eggs hatch in due course, and the grubs of the ichneumon flies burrow about in the tissues of their hosts, ultimately turning into pupæ either inside or outside the bodies of their victims. The gardener knows the depredations effected by caterpillars, and anyone who examines a fence or wall near a field of cabbages at one of the periods when a brood of the caterpillars of cabbage white butterflies are about to pupate can acquaint himself with the toll exacted by the ichneumon fly on these devastators of the country's cabbage-supply. Many of the larvæ that were about to change into chrysalides will be found to be empty husks covered with a number of the pupæ of the ' fly,' their unbidden guests.

Parasitism is an ugly story, regarded in itself, and children should have the matter presented to them in the light that it is Nature's way of ensuring that no particular race of organisms shall become too dominant—in their own interests as well as in the interests of other organisms. To revert to the aphides, to which we referred in the preceding chapter, if they were not kept in check they would soon multiply at a rate much greater than perhaps we realize, wipe every green plant off the face of the earth, and, in their success, contribute to their own undoing, as there would be food neither for themselves nor for anything else. Unless this view of the case is put before children the idea of " Nature red in tooth and claw " may become established. Although Nature appears to be cruel, and probably is to some extent, she is not so cruel as we, who profess to resent cruelty, are. The caterpillar infested with ichneumon grubs appears to suffer no inconvenience and goes on with its preparations for pupating as though it were a normal larva. Probably the constant apprehension that animals appear to feel is the keenest disadvantage under which they suffer. Unfortunately we do not know enough about animal psychology to be able to form any idea whether this apparent apprehension amounts to the mental anguish experienced by most human beings when they are confronted with danger to life. We do know that many people do not experience anxiety in such circumstances, though they are none the less on the alert, and this absence of fear has earned for them a reputation that " They don't know what fear is," though we must be careful to remember that many sensitive beings are able to conceal their anxiety. Experience gained in the War tended to show that many men did not experience the sensation of fear, and that this attitude toward danger was in many cases associated with widely differing types—those of tremendous physical fitness, those of low mentality, and those of high mentality that enabled them to exercise complete control over their thoughts.

We will proceed to examine a few instances both among plants and animals in which we have to deal with cases of indubitable parasitism, and then go on to consider those in which co-partnerships have been established. We shall see that parasitism among plants and animals is no less disastrous to the bodily character of the parasite than it is to the personality of human parasites who prey upon their fellows instead of working for their own livelihood. Among plants one of the most common parasites is the dodder (*Cuscuta*), of which there are several species preying upon such plants as clover, flax, heather, nettles, thistles, and thyme. Parasites are always characterized by the degeneration of most of their organs, but their organs of reproduction are a startling exception, and illustrate the rule that the chief purpose of the species is the perpetuation of its kind. In all parasitical plants and animals the reproductive organs are extremely efficient ; the energy used up by most organisms in maintaining vegetative growth goes, in the case of parasites, to strengthen the powers of reproduction. Whereas, then, the dodder exhibits few of the characteristics of other green plants, its flowers are typical, complete, and well developed. So far as we know, it gives nothing to its host in return for what it takes from it. Instead of obtaining its salts from the earth by means of roots in association with the soil, and its starch from the air by means of green leaves, it sponges upon the plant to which it has affixed itself. Like many other parasites it begins life as a self-supporting organism. The seed, which has been deposited upon the earth, is well supplied with nutriment, and the embryo suffers no disadvantage at the outset, though its root is very obviously intended to be a temporary expedient. It grows down into the soil, however, and functions as a root, while the stem grows and develops small scale-like leaves, which remain small and do not turn green. Since they will not have to act as starch factories for the plant there is need neither for size nor greenness. The stem develops at an enormous pace. When it touches a plant suitable to it as a host it twines itself round it. This embrace is not merely an encircling one ; by putting forth processes which become probing suckers penetrating into the tissues of its victim it absorbs the substances that are being prepared by the host plant for the purposes of its own growth and multiplication. The dodder has no more need of green leaves and of roots than a human sponger has of tools or the will to work, and the root, having served its purpose in supplying water so that the stem might develop sufficiently far to seize upon its host, disintegrates. The plant now has contact with the soil only through the tissues of its original host and those of other plants to which it spreads as the tips of the new growths come into contact with additional sources of nutrition. Frequently it kills its host and would thereby starve if it did not possess the power of spreading itself rapidly. The dodder is a mean and pallid little thing, doing no work and having little need of sunlight. As we have observed, however, as a parent it is a great success ; clusters of flowers become associated with nearly all the leaves, such as they are, but the flowers are less conspicuous than they would be if they did not resemble so closely in colour the stem and leaves. Effort should be made to find examples of the plant and examine the flower with a lens. Each possesses a calyx formed of five sepals, five petals, and five stamens. Covering the ovary are five scale-like bodies projecting inward from the corolla formed by the petals, and there are two styles. Each flower gives rise to four seeds. Nectar is produced, encouraging cross-fertilization. It will readily be appreciated that the dodder is well able to hold its own and to make its way in the world.

We have endeavoured to draw our examples from organisms existing in our own country, and, so far as possible, from those that can be seen and handled by children. We are faced with a difficulty so far as parasitism among animals is concerned, because the subject is generally regarded as an even less comely one that it is among plants. The teacher will show a natural reluctance to deal with some of the more obvious examples that will suggest themselves, readily available to us though they be. In view of the menace with which we in this country appear

XIII. A BEECH-WOOD (*Fagus sylvatica*)

The dense foliage in summer and the fall of leaves that decay very slowly hinder undergrowth.

Photo E. W. Royston

now to be faced in the form of malaria, because of the astounding life-histories it illustrates, and because it will serve to introduce to children the great debt that we owe to biological research, it is proposed to use the malarial parasite as our example of animal parasitism. Probably there is no more outstanding example of the great contribution biological science has made to the succour of suffering humanity than that provided by the discovery of the true nature of malaria. Biologists not only discovered its cause, but within ten years of the discovery the whole life-history of the responsible parasite was worked out, and with that came the obvious method of treatment—not of the disease, but of its cause.

We have dealt with the life-histories of insects, and have learned that most insects pass through some kind of a metamorphosis. The common gnat is an insect the larval form of which lives in water, where the eggs are deposited by the female. The young larva attaches itself to the surface film of the water and hangs head down, breathing by means of a tube which is posterior and dorsal and protrudes into the air through the surface film. The mature insect is, however, a winged air-dweller, which possesses the power of ranging over considerable distances, but seldom travels far from stagnant or slow-moving waters. It is by means of a mosquito, an animal very similar to the common gnat of this country, and by the female only, that malaria is transmitted to man. The common gnat is the carrier of a kind of malaria to birds, but is no more capable of communicating it to man than the malarial mosquito is of transmitting human malaria to birds. In both cases, however, it is the female that is the culprit, for the mouth-parts of the male are too feeble to pierce the skin. Mosquitoes infested with malaria inject into the tissues of their victims 'saliva' in which are living forms, called sporozoites, of the malarial parasite. The infested mosquito appears to suffer no inconvenience from its parasites, and it is often the case when a parasite needs two

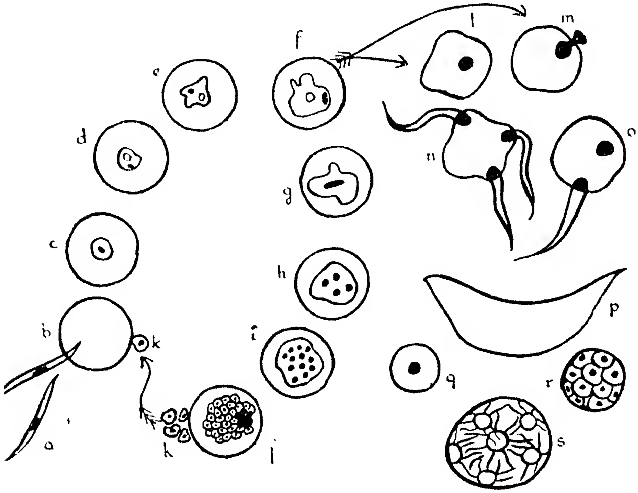


FIG. 22.—The life-history of the malarial parasite (diagrammatic). (*a*) Sporozoites from the 'saliva' of a mosquito entering (*b*) human red blood corpuscles. (*c*) (*d*) (*e*) (*f*) Development of the trophozoite stage. (*g*) (*h*) (*i*) Resulting formation of (*k*) merozoites, which attack fresh corpuscles and in due season produce more merozoites. But conditions arise when each trophozoite becomes either (*l*) a microgametocyte or (*m*) a macrogametocyte, which may be regarded as sexual forms. A microgametocyte produces (*n*) a number of microgametes, each of which (*o*) fertilizes a macrogamete, which is a macrogametocyte that has ejected part of its nucleus. The result is the formation of (*p*) a zygote, which turns itself into (*q*) a cyst in the wall of the stomach of a mosquito. There it divides into (*r*) a number of sporoblasts, which in turn become (*s*) divided into a crowd of sporozoites. All figures are enormously enlarged.

different kinds of host to complete its life-history that in one it appears to produce no ill-effect. The saliva injected into its human victim by the mosquito probably serves the purpose of preventing the blood from coagulating and makes possible a long drink, but it carries with it numerous sporozoites, microscopic in size, spindle-shaped, simple, one-celled protozoa. Each of these, getting into the blood-stream, begins to attack a red corpuscle, boring its way in by its pointed end. Once a sporozoite has effected an entry it changes its shape, and is then known as a trophozoite, resembling an amœba, an animal that has been referred to in Chapter II, and enlarges itself at the expense of the corpuscle until it completely fills it. It now divides into a dozen or sixteen organisms, to which the name of merozoites has been given, and the corpuscle having been by this time completely destroyed they break through and enter the plasma of the blood. An attack is made upon fresh red corpuscles, and, as it will be seen that the organisms are now about twelve times as numerous as before, the amount of damage they cause can be imagined. Each one fills a corpuscle and becomes a trophozoite, which breaks up into merozoites again; and this method of reproduction goes on, the number of red corpuscles attacked becoming greater each time. The time taken for the completion of the cycle varies with different kinds of malaria, but the periods of distress and shivering of the patient are synchronous with the attacks of the merozoites on fresh corpuscles, enormous quantities of which are destroyed during the progress of the disease. Thus a condition of anæmia is produced, while there accumulates a substance thrown off by the parasites which finds its way into various organs of the body. It might be thought that such a disease must always end in the death of the victim. As, however, the death of the victim would involve the death of the parasites, no good purpose from the parasite's point of view would so be served; indeed, if patients generally died the disease would be stamped out, as in the stages we have examined so far the mosquito could not make use of the infected blood to transmit the disease. In due course, and it is not certain what determines when this should be, the trophozoites, instead of attaining the form that preceded division into merozoites, become changed into two different forms, which may for convenience be called parent females (macrogametocytes) and parent males (microgametocytes). If these remain in the human body, having attained these forms, as most of them do, they inevitably die, but if a mosquito bites a patient whose disease has reached this stage some of them are drawn up in the blood of the patient, together with their fellows in all different stages, into the body of the mosquito. All but the gametocytes are digested by the natural processes taking place in the insect's body, but the gametocytes are able to resist those processes. They break away from the remnants of the corpuscles they inhabit, and the female forms pass through a process familiar to those who have studied the behaviour of such minute organisms, and become macrogametes —female cells awaiting fertilization ; the parent male forms undergo a very much more elaborate preparation, each one ultimately dividing into eight microgametes, which break away from one another. When the large female forms come into contact with the smaller male forms they unite in pairs, and each pair become a zygote, or fertilized cell, in the alimentary system of the mosquito. Now the zygote has a very different shape from the globular shape of either of the forms which coalesced to form it ; and it and its fellows become almost vermiform and bore their way into the wall of the stomach of the mosquito. Here they rest and acquire a form in which they are known as oocysts, globular again, feeding by absorbing the substance of their hosts. As the oocysts grow they tend to protrude into the alimentary canal of the insect, and begin to divide within their cell walls. Each of the smaller bodies now formed is known as a sporoblast, and proceeds to convert itself into a number of sporozoites like the forms with which we began our inquiry into the life-history of the parasite. When the sporozoites fill the oocyst to bursting point, rupture of the wall of the cyst discharges them into the blood of the mosquito, by which they are carried into its salivary glands. The mosquito is now ready to infect any unfortunate person it may choose to bite. The rest we know.

The difficulties with which investigators were faced when they came to inquire into the nature of malaria can be imagined by those who have followed the account given in the last few pages. The writer has always felt that an account of those investigations might provide an interesting story for school reading. The different forms assumed by the parasite at different stages of its life-history were sufficient to baffle the most tenacious investigators, and they did baffle them, for many thought, as was natural, that the different forms were different organisms. Once, however, the part taken by the mosquito in propagating malaria was understood its activities were immediately curtailed, for the life-histories of mosquitoes and gnats were known, and since they could not profitably be chased with butterfly-nets it seemed that to deprive them of their breeding-places offered the best solution. Consequently, all the stagnant waters in certain districts infected with malaria were covered with a thin film of petroleum, to prevent the mosquito larvæ from breathing through the surface film, and the effect was soon noticeable, the number of mosquitoes diminishing and fresh malaria patients failing to appear. Tracts of country at one time uninhabitable have become wholesome resorts even for white men, and it is no exaggeration to say that had the cause of malaria never been discovered the Panama Canal would have been an impossibility. The influence malaria has exerted upon the history of the world can be imagined from the fact that in three months, during the Walcheren Expedition, in 1809, of an army of nearly 40,000 men over 10 per cent. died of malaria and nearly 27,000 were admitted to hospital. In the Greek and Roman wars the disease must have been a great factor, to which consideration is only now being given.

We have next to examine another type of association, of which examples are hardly less numerous than are those of parasitism. This has been described at the head of the chapter as co-operation, but it is generally known as symbiosis. A great deal has been written about this subject, and it has appealed so strongly to the popular imagination that the bounds of truth have not always been observed. In cases of symbiosis both organisms benefit from the association, and neither harms the other, while in ideal cases each is practically dependent on the other. Lichens, among plants, provide the best examples, and are available almost everywhere for school study. The commonest species belong to a genus known as Parmelia, and examples are found on tree-trunks, where they form more or less circular patches measuring several inches across, grey or grey-green in colour, the edges having raised lips. Lichens are non-green plants (fungi) living in association with simple, green algæ, and the association enables them to spread over a very wide area and to exist in conditions in which neither the fungus nor the alga could exist by itself. The fungus grows round the algæ cells and protects them, and provides the means of adhering to the bark or rock ; it protects the algæ from desiccation, which would mean death to them, absorbing large quantities of water in which the necessary mineral matter is dissolved and air containing carbon dioxide ; while on the other hand the algæ, which possess chlorophyll, absorb the energy of the sunlight and so convert the salts and carbon into organic substances needed both by the fungus and by themselves in extending the colony and producing spores and, in some cases, ‘ buds.’

It is worth while to separate, as it were, in our minds the two organisms with which we are dealing. The fungus can grow in a manner common to fungi by absorbing liquids containing organic matter in solution, but it cannot make use of the sunlight, as do green plants, for abstracting the carbonic acid gas from the air. The algæ cells, on the other hand, grow and multiply provided they have access to water containing the usual mineral matter in solution and to air and light. Fungi usually grow and feed only underground, and the reproductive organs alone grow toward the light, so growing not because they need the light, but to enable their spores to be scattered. The association of fungus and green plants in the form of a lichen exhibits a very different method of life from either of these, for the lichen is able to take up, and flourish in, its position by circumstances which could prevail only by means of such an association. The consequence is that otherwise bare rocks offering neither the dead organic matter needed by the fungus nor the water required by the algæ become populated. The system of reproduction is naturally complicated, because it involves not only the reproduction of the algæ by a process with which we are familiar—the simple division of the individual cell of which each alga consists—but the more elaborate system of a fungus. The lichen is propagated by means of spores produced by the fungus alone in receptacles which are differently shaped in the various species. The spores are distributed by the wind, germinate if they find a suitable resting-place, and begin to put out threads. But growth soon stops unless the cells of the green algæ needed by the particular species of fungus are encountered. When such a meeting is effected the threads growing from the spore surround the algæ, and the lives of the fungus and the algæ are united in the life of a new type of organism—a lichen. In some cases, however, detachable buds containing the algæ already present in the lichen are produced, and are carried by the wind to places in which they can commence a fresh period of development, and in such cases the risks of a chance association in the new habitat are avoided. As, however, the algæ which are associated with lichens are very widely distributed and common, the prospect of the formation of a fresh organism can depend mainly upon a spore alighting in a suitable environment with every certainty that the species will be maintained.

The number of species of lichen is large, and they adopt very different shapes. The species we have had in mind is an example of a very common form familiar to all, though unfortunately but few realize how interesting a method of life is concealed within those green, brown, or grey lobes. Between the lobe-shaped growth of Parmelia and the thread-like Usnea is every conceivable intermediate shape, while the colours of different species, and the colours of their spore fruits, vary greatly, from the rich green *Peltigera canina*, growing among damp undergrowth, to the orange *Peltigera parietina*, which covers roofs and walls, and the black and white of *Lecanora atra*. The reindeer ‘ moss ’ (*Cladonia rangiferina*) is a lichen which, most school-children know, provides sustenance for the reindeer during periods when other food is scarce, and is of interest because it produces erect stalks which are branched and bear the fruits. But it is with the co-operation of the green plant and the fungus that we are chiefly concerned ; it provides in the school an interesting type upon which to give a revision lesson on plant nutrition.

CHAPTER XIII

CARNIVOROUS PLANTS

THE general principle that appears to emerge from the chapter on " The Origin of Life " is that animals in the main prey upon plants, and that even carnivorous animals like the lion are dependent for their food upon animals that live upon plants. Further, we were forced to the conclusion that before animal life existed on the earth there must have been green plants to manufacture food for them. So fundamental appear to be the facts of the modes of nutrition of plants and animals that it comes as a surprise when we are reminded that there are such organisms as plants which prey upon animals. It seems to demand a fertile imagination to believe that plants firmly rooted in the soil may seek sustenance from the bodies of active insects, and hardly anything more subversive of ordinary experience can be thought of than a geranium plant chasing a bluebottle fly through the air. Of course, all plants are dependent upon the detritus of their own and animals' bodies for the substances upon which they live and grow and multiply, and, although no one supposes or would believe that a geranium plant chases animal prey, it is nevertheless true that some plants—regarded from a world-wide point of view, many plants—do attack animals, kill them, break down their tissues, and feed upon their juices. These plants are immotile, fixed to the ground by their roots and unable to dispense with any less firm anchorage. They exist in this country and may frequently be found, although they are restricted to certain conditions.

The pedestrian traversing moorland may quite commonly come upon a plant having many pale green leaves produced from a short stalk, which are flattened close down upon the ground. This is the butterwort (*Pinguicula vulgaris*). The flower stalks project boldly into the air, standing quite clear of the leaves, each bearing a blue flower, consisting of a calyx composed of five sepals, a large corolla formed of five unequal petals with its base produced backward so as to form a spur to contain nectar, two short stamens, and a spherical ovary bearing a style with a double stigma. Bees visit the plant with impunity, because they are concerned with the flower, which is cross-fertilized. But it is with the leaves we are chiefly concerned in this chapter, for they function almost like the stomachs of animals. While the under sides of the leaves are smooth the upper bear quantities of glands, some of which are raised on papillæ, producing a rough appearance. If the upper surface of a leaf is touched by the finger it will be found to be covered by a sticky substance secreted by the glands. When flies alight upon it they are held fast, while the leaf begins to curl slightly inward and the glands exude a substance that has the same effect as the digestive secretions of animals. The bodies of the flies begin to dissolve, and all the assimilable matter is absorbed by the substance of the leaf. If a piece of cooked egg or meat is placed on a leaf, the same activities are manifested, any albuminous material being dissolved and absorbed, but insoluble matter leaves the plant unmoved. We have a process in operation that is generally regarded as purely animal. But the plant is not dependent upon such methods of feeding, because it can manufacture its own food by means of its chlorophyll.

In some respects an even more remarkable plant is the sundew, the most abundant species of which is the roundleaved sundew (*Drosera rotundifolia*) which is often found in close association with the butterwort. Upon the waterlogged parts of moors, among mosses, it can frequently be found. It is easily recognized. Like the butterwort it has a short stem, and its leaves, which spread out from the centre on long stalks, are circular and covered on their upper surface with red tentacles each of which has a swollen head containing a gland. The tentacles lend to the plant a ruddy and aggressive appearance. The gland at the end of each tentacle secretes a mucilaginous substance that looks like a bead of glistening water, a characteristic to which the plant owes its name. The tentacles are much better developed toward the margins of the leaves than they are toward the centres, where they consist of nothing more than greenish stalks. They exist to attract and trap insects, which come, presumably, to sip the apparent nectar, but once they alight for this purpose they are held by the sticky substance and surrounded by the larger tentacles, which bend over and attach themselves by their viscous heads to the bodies of the insects. When a fly is seized the glands exude a digestive substance similar to that exuded by the butterwort, and its body is broken down, the soluble parts being absorbed. In the case of this plant too the same activities are set in motion by the contact of any albuminous material. When plants are introduced into the school, as they may quite well be, it is desirable to employ pieces of meat as food rather than living insects, but they do not respond to drops of rain or to other non-nitrogenous matter. The sundew can be kept quite satisfactorily in plant-pots filled with damp peat and moss. Its flowers are insignificant, and are borne on long stalks, and it will be seen with difficulty that each consists of a calyx composed of five green sepals united at their bases, five pink-white or violet-white petals, and five stamens surrounding a pistil surmounted by three stigmas. The ovary really consists of three carpels, but there is a single cavity. The seeds are distributed by the wind.

If we went farther afield and visited other countries, or if a visit were paid to Kew or any other well-equipped botanic garden, we should find yet further modifications to enable plants to make use of animal substances as food. These organisms are, nevertheless, capable of living without such additions to the normal diet of plants. Venus' fly-trap (*Dionæa muscipula*) is perhaps the most commonly spoken-of carnivorous plant, and here again it is the leaf, strangely modified, that secures and eats the unsuspecting insect. The leaf-stalks consist of two parts, one performing the normal business of a leaf, building up tissue by means of its chlorophyll, while the other, upper, part consists of two valves each of which possesses a row of ' teeth ' along its free edge. The valves are so sensitive that immediately an insect touches any of the hairs with which they are furnished the valves close, and the victim, which was attracted by the nectar invitingly displayed at the tip of the leaf, is deluged with a sticky substance which acts as a digestive, and undergoes a fate similar to that meted out by the butterwort or sundew. When all that is soluble has been extracted the valves open and lie in wait for new visitors.

But most arresting of all are perhaps the pitcher-plants, of which there are many kinds widely distributed throughout the world. Specimens that may be easily grown in any heated greenhouse develop pitchers several inches in length, and the fluid therein may be inspected and found to contain insects in various stages of dissolution. The pitchers are modified leaves, which bear on their inner surfaces numerous hairs that point downward, and hold the fluid that lures flies and bees to their destruction. The hairs are so disposed as to enable the insects easily to enter the pitchers, but if they try to withdraw they find their egress closed, for the hairs are directed toward the contained fluid and behave like the strands of a lobster-pot. If the victims attempt to alight they find a slippery and insecure foothold, and they are equally unsuccessful if they endeavour to escape by flying straight upward ; the margin of the pitcher hangs over in such a way as to cause them to fall down into the liquid, which speedily drowns them and converts them into substances capable of being absorbed by the plant. Many species are so large as to trap big moths, and travellers' tales refer to even larger growths that are a menace to higher animals.

Then there is the lady's slipper (*Cypripedium calceolus*), which has so developed its flowers—not its leaves—as to form traps for insects, the bodies of which it converts into food ; and the bladderwort, an example of somewhat different processes, for it does not possess the power of exuding a digestive ferment. The bladderwort is found in ponds and lakes suspended in the water, and is commonly met with in the Broads of Norfolk and Suffolk. It consists of a series of branches bearing leaves that are so finely divided as to be hardly more than threads, and it has no differentiated root. The flowers are yellow, comparatively large, and are borne on large, long stems which seem to be out of all proportion to the rest of the plant. The bladders are modified leaves attached to the stem by a short stalk and are shaped like bags, each of which has an opening surrounded by branching processes. The mouth of each bladder is furnished with a lid or valve that will open inward, but cannot be pushed out by any force that can be exerted from within. Small crustacea force their way in, but cannot escape, and when they die the products of their bodies are absorbed by the plant.

Why have a number, a comparatively small number, of plants adapted themselves to a mode of life and, in part, a diet so different from those of others ? It will have been observed that the plants we have dealt with in this chapter are marsh plants, and it can only be supposed that the conditions in which they live prevent them from obtaining in sufficient quantity by normal methods certain substances which other plants derive from a different environment. Other marsh plants manage to thrive either by adapting themselves to needing less of these elements or by securing them in some other way. Carnivorous plants have developed the power of obtaining them, particularly nitrogen, directly from the bodies of animals, and in the cases of butterwort and sundew it is doubtless the scarcity of nitrogen that leads to the activities that have been described. Darwin experimented on the leaves of the sundew and found that the richer in nitrogen the substances offered the plant for food the greater were the activities into which the tentacles engaged, and the greater were the number that entered into action ; substances possessing little nitrogen, on the other hand, excited interest only in the tentacles in immediate contact with them, while non-nitrogenous matter ' left the plant cold.'

In the cases of some of these plants we have a process approximating so closely to the digestive processes of animals, and of highly developed animals too, that it is impossible to say that there is any essential difference. In what respects can the bladders of bladderwort be said to be different from a series of little stomachs, which they resemble closely in shape, and, to some extent, in function ? And in function do not the leaves of butterwort and sundew resemble the stomachs of animals ? As regards the pitcher-plants, we again have leaves performing not only the function of stomachs, but resembling them in shape—sacs into which food passes and in which it is first rendered solvent and then absorbed, just as the digestive tract of an animal dissolves and absorbs nutritive material. Both animals and the plants we have been studying steep their food in liquid produced as a result of the excitation of special cells by the food itself. The process of digestion is a process of fermentation in both cases, and, although more is known of the digestive processes of animals, we are forced to the conclusion that they are so similar as to be indistinguishable. The glands that secrete the digestive substances can be examined under the microscope, and the inner wall of a pitcher-plant's trap, so examined, is seen to bear a remarkable likeness to a portion of the lining of an animal's stomach.

We are so accustomed to regard it as ' natural ' that animals should prey upon plants (because we cannot avoid the conclusion that it represents the natural order of things in consequence of the probability, or almost the certainty, that plants existed before animals) that the facts regarding insectivorous plants produce almost a revulsion of feeling and sometimes a conviction that things are not as they should be. But reflection will certainly remove any such feeling, and it cannot be argued that the established order of things is natural and proper, but that the act of retaliation on the part of a small group of plants is retrogressive and evil. We are too prone to accept evil provided it is accepted at large, and to repress the innovator. After all, it has to be borne in mind that insectivorous plants perform their part, a small one though it be, in maintaining a balance that protects us from being totally consumed by those very successful animals, the insects. But as a crumb of comfort for those who cannot reconcile themselves to what they will perhaps continue to regard as an unnatural state of affairs, and to help them to understand that Nature, after all, looks after the most resourceful and efficient at the expense of the unimaginative and inefficient, it can be related that some tropical pitcher-plants are exploited by dipterous flies which deposit their eggs in the masses of decaying insects in the pitchers, and that the resulting grubs rob the pitcher-plants by feeding upon their stores of nourishment. But wait! Lemurs and insectivorous monkeys exploit in turn the dipterous flies, for they prey not only upon the decomposing food-stores of the pitcher-plant, but upon the fine, fat larvæ of the flies, and it is probable that it is for these principally they come, merely contenting themselves with the dead flies if larvæ are not present. It would appear strange that substances which play havoc with the bodies of trapped flies should leave unharmed the eggs and resulting maggots of other flies, but the eggs and maggots are probably furnished with substances that neutralize the digestive ferments of the plant. After all, there are among animals numerous examples of parasites that can exist undigested in the digestive tracts of a particular species, but are promptly killed and digested by another species, and even of parasites that can so exist in one stage of their life-history, but not in another. The reader who has apprehended the life-history of the malarial parasite will appreciate this, but there are many similar cases known to parasitologists.

CHAPTER XIV

COLOUR IN ANIMALS AND PLANTS

THERE is nothing that so seldom raises the inquiry " Why ? " from the lips of children as the diversity of colour in plants and animals. They seem to accept colour in nature as it stands, and seldom ask why colour exists or what it is. On the other hand, once an interest in colour has been aroused, there are few aspects of nature study that appeal more to the youthful mind. To many an amateur entomologist the study of insects is synonymous with the study of colour. It must be admitted that among insects we find not only the most vivid combinations and patterns, but the most amazing examples of sympathetic or protective coloration. The boy finds a singular delight in taking his non-biological friend to a privet hedge and asking, " Can you see that caterpillar ? " " No," says his companion at once. " Well, you must be blind," he retorts ; " look, it's four or five inches long, a great, big, green thing with violet stripes and a black and yellow horn. Can't you see it ? " Again he is assured that it does not obtrude itself on the vision, and he then triumphantly points out a caterpillar of the privet hawk moth (*Sphinx ligustri*) which, when once seen, stands out most conspicuously from its surroundings. Now the privet plant consists of slender twigs bearing small ovate leaves, and the privet hawk caterpillar is a large, fat larva which it would appear difficult to conceal ; but an artist would experience no difficulty in appreciating the fact that it merges so well with its surroundings as to be all but invisible except to the eye trained from early youth to detect it. It normally frequents the tall branches of the privet hedge, and is, therefore, generally viewed from a position inferior to itself. The ground colour is a green that exactly matches the under sides of the privet leaves, which are lighter than the upper, and the expanse of body is broken up by the violet stripes. The stripes are parallel and lie diagonally to the segments of the body, creating an impression of a row of privet leaves, and we are assured by artists that green throws a violet shadow. The horn is so curved as to suggest a single leaf viewed laterally, or a petiole. But an extraordinary point about this insect is that it feeds also upon lilac and ash, both trees with considerably larger leaves than those of the privet, but leaves lighter in colour, blending more readily with the colour of the caterpillar, so that the stripes do not appear to be so necessary to insects feeding upon those trees. However, it is no easier to detect the caterpillar on these than it is on privet.

What, then, is the reason for these colours, and whence do they come ?

To answer these questions we must go back a very long way, and the farther we carry our investigation the more likely does it appear that the colours of animals now serve a secondary purpose, their original or primary purpose having been nutritive. When we consider, as we have considered in Chapter III, the significance of the almost universal green of plants, we can understand the nutritive purpose served by it. In recent years attention has been drawn to the fact that there are certain colours that appear in animals almost as persistently as green does among plants. Investigations that have been made show that in some animals these colours—yellow and brown—beside being protective also serve a nutritive function ; it has been suggested that in the past they may have been of greater importance to animals, or the forms of life from which animals developed, than they are to-day. Are these colours survivals of a time when all living matter was nourished by the agency of a yellow or brown pigment ? Did plants convert it into chlorophyll, while animals, adopting a method of feeding by ingesting organic matter, retained it unchanged ? Or was chlorophyll, as we are inclined at present to think, the means by which all living things were nourished ? In the latter case the yellow and brown pigments in animals may be merely the remains of the green pigmentation which, when the animal system of nutrition was evolved, ceased to be the sole or principal agency.

If we search among animals for a pigment which is as universal among them as the green pigment is among plants, we shall doubtless fix upon the red pigment of the blood as being comparable, and there is no doubt but that this red pigment, which has been referred to in Chapter IV, bears a close chemical, and perhaps an historical, relation to the green pigment of plants. But, as we have seen, the hæmoglobin which gives to the blood of higher animals its characteristic colour serves a respiratory function, fixing the oxygen from the air in order that the whole body of the animal may breathe and live. However, the relationship between the green colour of plants, the yellows and browns to which we have referred, and the red colouring matter of the blood of higher animals is but imperfectly understood, and hypothesis has not so far led to any definite conclusion.

So much has been written on the subject of the colours of animals, with which in the main we have to deal, that the reader who wishes to pursue the matter farther than we shall take him will have no need to seek far for his literature ; but for most of us observations that can be carried out in and around the school will suffice. Probably the first thing that will occur to anyone thinking the question out for himself will be the almost universal rule that upper surfaces are darker than under surfaces. It is true that the action of light tends to the development of pigment. The under sides of the leaves of a plant are lighter than the upper sides, and we expect this, because there would be, we should suppose, a greater use for the masses of chlorophyll on the surfaces upon which the light acts ; but we must bear in mind the action of other forces, such as that which colours the under sides of the leaves of the water-lily with anthocyanine for another purpose.[1] A fish's belly is white, or lighter than its back, but we must remember the curious exception of the tropical sucker fish (*Echeneis remora*), which lives attached by its modified dorsal fin to the back of its ' host,' and has a black belly and a white back ; in this case, however, the normal position of the belly is uppermost, and it is upon this that the light plays, and not upon its back, so that there is here no exception to the rule that the surfaces exposed to light develop more pigment than those that are shielded. It is obvious that anything looking down upon a fish in the water would have difficulty in seeing the dark back, which would harmonize with the shadows of the depths. Similarly, anything looking upward toward the surface of the water would be less likely to see the white belly of a fish against the light of the sky than it would a dark object, which would be silhouetted against the light. Although we must remember that the belly of the fish would be in shadow and that it would not be so inconspicuous as at first thought we might suppose, we cannot, nevertheless, escape the conclusion that fish do obtain some measure of protection by having dark backs and light bellies. We should do well, too, to consider the appearance of a fish from a lateral view ; artists will tell us that a dark top becoming lighter below is known among them as ‘ effacing gradation.’ In studying the coloration of fishes we cannot take a more interesting example than that of the perch (*Perca fluviatilis*), a common fish in both lakes and rivers, which cruises lazily in shoals among the weeds or the piles of landing-stages. Its well-known striped back needs no description ; it serves admirably to conceal the fish, because the stripes resemble so closely the shadows cast by the weeds and the piles. The pike (*Esox lucius*), a very attractively coloured animal as seen when withdrawn from its natural surroundings, passes unnoticed amid the weeds in which it lies in wait for its prey, since its markings break up its surface in such a way as to cause it to be almost indistinguishable from the weeds.

---

[1] See Chapter VIII.

Plants, on the other hand, it is to be observed, do not try to conceal themselves, but have developed a flowering habit with a view to making themselves as conspicuous as possible. The existence of conspicuous flowers is, we believe, designed to encourage cross-fertilization. Their seeds, however, containing a store of nutriment for the young plants, usually are so coloured as to blend with the conditions among which they find themselves when they are shed ; but it must be observed that fruits containing seeds are often gaudily coloured, presumably with a view to attracting birds that will, by feeding on them, act as disseminators. Can we go so far as to say that those plants which produce seeds resembling caterpillars, snails, and other succulent morsels have found the practice profitable, in that insectivorous birds mistake the seeds for animal matter and distribute them widely before dropping them on realizing their mistake ? The idea is not to be lightly dismissed.

But it is among animals we shall find the most interesting colour studies. Among birds and insects we discover amazing and intense coloration. We have already referred to the suggestion that pigmentation was primitively associated with a nutritive function; we mentioned the probability that, when animals perfected the system of taking organic food and breaking it down prior to assimilation in an alimentary tract, the nutritive pigments were retained. Possibly they became modified, acquired a greater affinity for oxygen, and were utilized for the purpose of a more perfect respiratory function necessitated by or giving opportunity for increased powers of motion. It is necessary to grasp this, because it is from the blood pigments in the main that the colours of animals are elaborated by processes of excretion. It is believed that when the pigment of the blood has served its purpose sufficiently long it is broken down, probably by the action of heat, and converted into substances that under the influence of light and air give rise to the diverse colours with which we are acquainted in the animal world, being deposited in skin, hair, feather, and scale.

But what is colour—or, rather, what is it that causes colour? What do we mean when we say that a dandelion is yellow, a dragon-fly blue, a polar bear white? We know that ordinary white light is derived either directly from the sun or indirectly from the sun by the combustion of substances that have been exposed to the sun. The colour of any particular object is, however, not due to anything within it, but to the light that strikes upon it and to its treatment of that light. It is true to say that a substance enclosed in an absolutely light-tight box is colourless, but the difficulties in the way of demonstrating this are obvious, as without light we cannot see. Most materials possess the power of absorbing certain of the colours of which light is composed, and the colour a substance is said itself to possess is the colour or colours it does not absorb. Some substances absorb hardly any of the light, and these are white;

others can absorb all, or nearly all, and these are black, or nearly black ; it should be observed that we do not meet in practice with any really black object—if we did we should not see it at all. The flower of the dandelion is yellow because it possesses pigments which absorb all the light rays except the yellow ones, and as they reflect back the yellow ones we say that the dandelion flower possesses yellow pigment. A blue flower absorbs all the rays except the blue ones, and a white one absorbs none. It is advisable to understand, if only superficially, the theory of colour. It is often said that the white coats of most animals that live amid Arctic snows protect their owners by making them indistinguishable from their surroundings, and doubtless they do reap some advantage in this respect. But the primary purpose of the whiteness is to protect them from intense cold. White is not a colour, but is the result of combining all the colours. Instead of there being pigments that absorb certain colours and reflect others in the feathers and hairs of white animals, there is a mass of air bubbles, like minute soap bubbles, which reflect all the light. Moreover, the aggregation of air spaces acts as a non-conductor of heat and keeps the animals warm by conserving the heat produced by their own bodies.

As a whole, the colour system of the animal world is generally ‘ protective ’ or ‘ sympathetic,’ but we shall have to consider an important group which possesses ‘ warning ’ colours. The apparently conspicuous tiger is almost invisible amid the reeds and undergrowth of its home, and the stripes of the zebra afford that animal similar protection. The dappled giraffe and the spotted leopard blend perfectly with the patches of light and shadow thrown by the sun shining through the branches of trees. Among birds even more startling devices obtain, and it is difficult indeed to avoid stumbling over the sitting partridge or grouse. Predatory animals are assisted by protective coloration, because they are able to stalk their prey or to lie in wait for it without attracting notice, and herbivorous animals by their chance of being overlooked by their enemies. But it is among the insects that the most amazing colour schemes may be studied, and with a little practice the teacher will experience no difficulty in introducing his pupils to numerous examples. We have already referred to a protectively coloured caterpillar, but the perfect insects often enjoy a no less efficient protection. The gaudiest butterflies offer some of the best examples. The small tortoiseshell (*Vanessa urticæ*) is almost invisible when its wings are closed, and so is the big peacock butterfly (*Vanessa Io*). Perhaps the most remarkable butterfly in this respect is the orange-tip (*Euchloe cardamines*), which has wings that are mainly white, the fore-wings being tipped with vivid orange. But the under sides of the wings blend perfectly with the umbelliferous flower-heads amid which it disports itself, and photographs of an orange-tip butterfly with closed wings on an umbel of wild parsley find the observer often unable to pick out the insect. Moths, which generally fly by night, need protection during the day, when they are resting, and we find that the under wings, which are covered during rest by the upper wings, bear the gaudier colours, but on their upper surfaces ; the large, shielding fore-wings, on the other hand, are so coloured as to blend with their surroundings. The most striking examples commonly met with are the moths called underwings, so named, presumably, because in every species the under wings are very brilliantly coloured while the fore-wings are grey or drab, according to the prevailing colour of the objects upon which the insects rest. One of the grandest moths found in this country is the red underwing (*Catocala nupta*), a large insect frequenting the vicinity of willow-trees, upon which its larvæ feed, and upon the trunks of which the mature insects rest during the day. An unobservant person may gaze upon the trunk of a willow upon which as many as three red underwings are resting without detecting them ; but let them be disturbed and they fly away displaying a great expanse of red under wing edged with velvety black, most conspicuous in flight. The number of examples might be multiplied almost indefinitely, but it is desired only to draw attention to the general tendency in the use of colour rather than to supply a list of examples, which students of Nature should seek for themselves.

Bordering upon the subject is the power of mimicry possessed by some animals. It is well known that harmless snakes will rear their heads and strike out in the most approved viper-like fashion ; the writer has repeatedly been ‘ bitten ’ by an ordinary grass-snake (*Tropidonotus natrix*), which possesses no power of harming except through the exudations of the anal glands. No doubt harmless snakes secure some protection by simulating the movements of poisonous ones. It seems desirable, however, to draw attention to one other common insect, the caterpillar of the puss moth (*Dicranura vinula*). It is not only protectively coloured, but possesses the power of assuming a terrifying attitude which is capable of implanting fear in the hearts of hungry birds. The caterpillar has a ground colour of green, with a saddle of mauve in the form of a diamond on its back, the lateral points of the diamond extending down the sides. It feeds upon willow and poplar, and the mauve marking, as can be well imagined, harmonizes well with the shadows cast by the green leaves. But the larva is of an extraordinary shape. The fore-part of the body is much the heavier, and the general effect produced by the head and the straight lines of the diamond marking is to create the impression that in transverse section the animal is square. From the head to the tail the body tapers to a point. The caterpillar looks capable of inflicting an injury even when it is at rest ; alertness is suggested by two black spots, one on either side of the head, which look like eyes, and it certainly does not invite the touch of those who are not familiar with it. But let the observer touch it, or even agitate the branch to which it adheres by means of its pro-legs, and it at once assumes an apparently threatening attitude that presages both biting and stinging : the fore-part of the body contracts and is reared into the air, while the tail is elevated, and whip-like processes are extruded. The head suggests the head of a snake drawn back ready to strike, while the tail hints at stings of a virulence compared with which that of a wasp would be negligible. Beyond this nothing happens, except that if the interference be maintained the head will probably be moved from side to side to ensure that from whichever side the enemy is attacking a good view is obtained. In the case of this insect we have an example not only of sympathetic coloration, but of mimicry, though he would be a bold man who went so far as to dogmatize upon what exactly is mimicked.

Most of us are familiar with the ‘ stick ’ caterpillars of the pepper moth (*Biston betularia*) and other geometers, and all of us with the ‘ stick insects ’ (*Bacteria trophinus*). In the case of the latter insect a point that is not always noticed, though it must have been possible for anyone who has kept these animals for any length of time to observe it, is the resemblance the eggs bear to seeds. It seems as though all through their life-history stick insects mimic vegetable products. In view of the fact that seeds are as much sought after by birds as are eggs, it would seem that the stick insect is not by this resemblance assisted in its struggle for existence as a race, because omni-

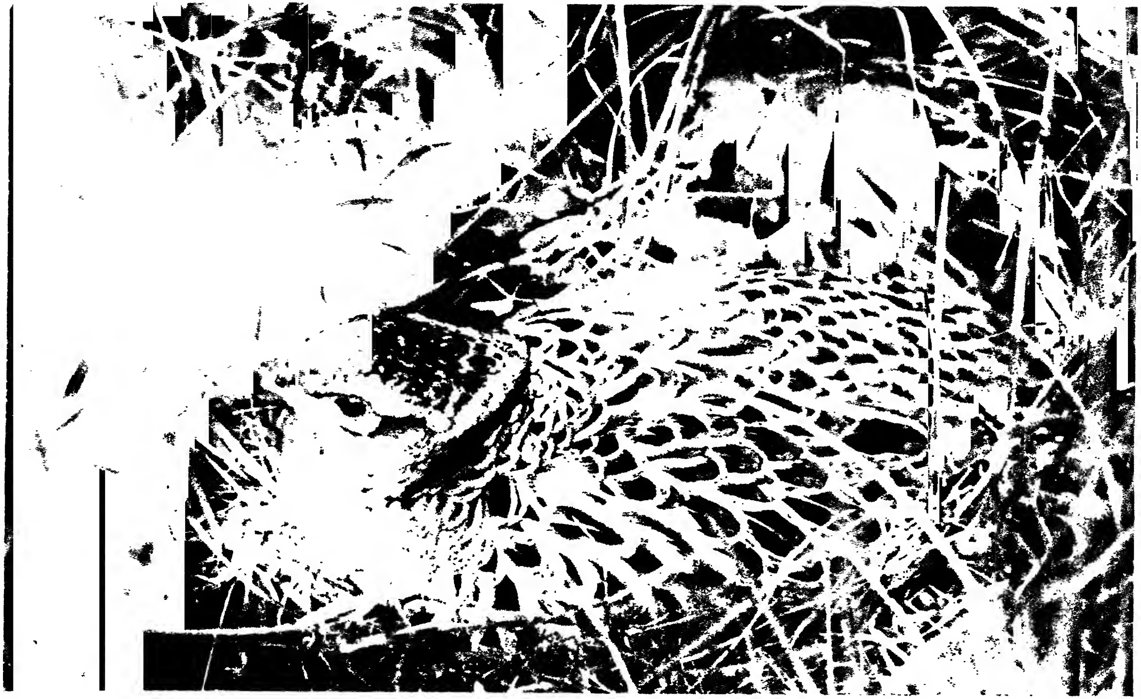
vorous birds would not reject the eggs if they picked them up under the impression that they were seeds. The resemblance is remarkable, for the eggs not only resemble radish-seed very closely, but actually bear nodules which with the naked eye can scarcely be distinguished from the points of attachment of the seeds.

Although, as we have before remarked, it is our desire so far as possible to confine ourselves in seeking our illustrations to examples that may be to hand in this country, it is impossible to pass over the classic case of mimicry by other butterflies of the Danaid butterflies of South America and Africa. The Danaids possess an objectional flavour which causes birds to reject them ; a number of other butterflies, not related to them, which possess no peculiarities that make them distasteful to insectivorous birds, so closely resemble them in colouring as to secure considerable protection from that resemblance, and it is presumed that birds are unable to distinguish between them. From what has already been written herein it seems hardly necessary to say that these insects cannot be accredited with deliberate and conscious mimicry—indeed, we have no reason for believing that even if conscious thought could be attributed to them they could influence their colouring. But we cannot avoid the conclusion that these two kinds of butterfly at one time in the past history of their races differed distinctively from one another, but that the descendants of the palatable ones which most closely resembled the Danaids were more successful. Owing to the fact that they were less molested they were better able to propagate their kind, and this led to the gradual extinction of those families that differed most from the Danaids. So, by a process of natural selection, types were evolved which resembled them more and more until in countless generations, perhaps fewer than was at one time thought, they came to be indistinguishable, so far as birds and other enemies were concerned, from the unpalatable Danaids.

It would, perhaps, be going too far to say that all animals that are conspicuously coloured are distasteful to other animals. Nevertheless, it is very often the case that strikingly coloured animals possess characteristics that cause other animals to avoid them. Hence the term 'warning colours.' But we must be careful to picture animals that are supposed to bear warning colours in their natural surroundings, and not to judge them as they appear to us in unnatural conditions, perhaps in captivity. White and black, and yellow and black, are the combinations we generally associate with ability to cause unpleasantness, yet white and black penguins and the yellow and black tiger are protectively coloured, as we readily appreciate when we think of them in their ordinary habitat. These combinations are, however, very frequently warning colours, and we have as examples the badger in this country and the skunk abroad, both of which can exude such perfumes as will cause carnivorous animals to give them a wide berth; and we are all familiar with the wasp. In mentioning this last we may add that a long list of dipterous and other non-stinging flies could be drawn up all of which bear yellow and black and acquire some advantage from a livery associated in the popular mind with a capacity to inflict pain. It is urged by some that the badger's decorative scheme is sympathetic, and those who have seen a badger in the heavy shadows of its native woods will not dispute this. But, the question will be asked, why are these creatures endowed not only with the power of being unpleasant when attacked, but with a ticket that protects them from molestation? The answer seems to be that at some time they acquired the capacity for unpleasantness, or developed a power that all or most animals had to some extent, and that this did not entirely protect them, because their foes often killed them before they discovered their mistake ; those, however, which possessed more conspicuous markings than their relatives were less often attacked and survived to produce progeny which, of course, tended to resemble their parents, and so by a process of natural selection only those survived which most boldly bore the motto *Nemo me impune lacessit.*

Many battles have been waged on this question of colour and its meanings, and many have been the attempts to overthrow the Darwinian doctrines on the subject of natural selection, but so far none of the onslaughts has been successful, and the theory of natural selection stands to-day as firmly as ever. Bright colours are usually associated with robust health, and the strong are more able to secure mates and to propagate their kind. Bright colours, as we have seen, are not always conspicuous, for in many cases the brighter they are the more they serve to conceal those who bear them. We cannot fail to inquire, however, why it is that so often in nature when both sexes are not equally adorned it is the male that is the gaudier. This tendency is most noticeable among birds, which have been the subjects of many investigations. The conclusion that has been reached is that the race cannot afford that both parents should have to expose themselves, as birds do, and that the female, which has to spend a greater part of its time confined to its nest, often on the ground, needs to be sombre. The difference in colour is almost universal among butterflies and moths, the males being usually smaller but more intensely coloured than the females.

Our observations on the colours of animals would be incomplete without a reference to what are known as 'secondary sex distinctions.' As has already been indicated the brighter colours of male birds and male insects are sex distinctions, but distinctions of only secondary importance. The primary sex distinctions are the organs which produce the cells which give origin to new organisms, which ensure the fertilization of the eggs and provide nourishment for the young in cases when the latter cannot immediately deal with normal food. These have been dealt with so far as was possible within the scope of these chapters. The teacher has close at hand many opportunities of drawing attention to secondary sex distinctions ; some have already been pointed out, but the existence of such distinctions among animals is the rule rather than the exception. There are few schools the pupils of which cannot be introduced to a peacock and a peahen, and even in remote districts these differences may readily be observed in a poultry run, for the cock of most domestic poultry is as clearly differentiated from the hen as in the case of the peafowl. Among domestic poultry the well-developed spurs of the males should be noticed, given to them because they are polygamous and in consequence fight for their consorts. The ruff and the reeve (*Philomachus pugnax*) were at one time more commonly met with than at present, but it is only necessary to draw the attention of children to the marked differences in the livery of the house-sparrow (*Passer domesticus*) to demonstrate not only the sex distinctions, but the extraordinarily beautiful markings of a bird which is generally ignored and thought to be drab and plain. The species of newt commonly met with here (*Triton cristatus* and *Lophinus punctatus*) exhibit such differences that the uninitiated may be pardoned for thinking that a pair consists of two totally different species. There are, among crustaceans and the round worms, even more remarkable differences, the differences in size between specimens of the two sexes being so considerable that in many cases the relationship was for long unsuspected. Then the insects present us with remarkable



XV. A HEN PARTRIDGE (*Perdix cinereus*)

An example of protective resemblance. The bird's coloration blends with the surrounding vegetation

Photo C. H. Royston

instances : the female of the vapourer moth (*Orgyia antiqua*) possesses only rudimentary or vestigial wings quite incapable of flight, and the males of most moths possess antennæ which are more elaborate than those of the females and are thought to be the seat of special sense organs which enable them to locate their partners. Indeed, among insects the inquiry could be conducted indefinitely. Most of us are acquainted with the differences in the sexes, and the modification of sex, among bees, wasps, and ants. We must perforce leave the subject with the hope that the teacher will have perceived the lines upon which lessons may be devised not only to encourage observation, but to develop power to see and to appreciate the amazing refinements that Nature has introduced the more effectively to attain her ends.

CHAPTER XV

DARWINISM

THE meeting of the British Association in 1860 was held at Oxford. Shortly before Charles Darwin had given to scientists his *Origin of Species*. To-day, when the doctrines therein set forth are universally accepted by all biologists whose opinions carry any weight, when those doctrines stand firmer perhaps than ever in consequence of the unavailing onslaughts that have been made upon them, it is difficult to appreciate the storm of ridicule they excited at the time. At this meeting Thomas Henry Huxley attended to uphold the new doctrine of the origin of new things, and he was asked by the then Bishop of Oxford, Samuel Wilberforce, whether he, Huxley, traced his descent from a monkey through his grandfather or his grandmother. The great Huxley replied with what is perhaps the finest and most scathing criticism that has ever been made upon those who will rush in where angels fear to tread; he said that no man had any reason to be ashamed of having an ape as his ancestor, but that if he, Huxley, could imagine an ancestor of whom he would be ashamed it would be a man of restless and versatile intellect who was not content with success in his own sphere, but plunged into scientific questions with which he had no real acquaintance, obscuring them with an aimless rhetoric and distracting the attention of his hearers from the real point at issue by eloquent digressions and skilled appeals to religious prejudice.[1]

Even to-day it is probable that Charles Darwin is known to the great majority of people as " the man who thought men are descended from monkeys," and the phraseology generally employed suggests not only that Darwin did set forth this doctrine, but that of course the present generation has successfully disposed of a ridiculous but somewhat uncomfortable theory. Nevertheless, at the time when *The Origin of Species* was first published, Darwin, knowing too well the strength of religious prejudice, had avoided any danger of exciting it by references to man's position in the scheme of things. In view of the very hazy notions many otherwise well-informed people have regarding Darwin and the theory of natural selection, it seems that the purpose of this book would be incompletely attained did it not include an attempt to set forth briefly some account of what Darwin had suggested in his *Origin of Species*. But should the impression be conveyed that such an account can be read instead of the book itself, the object aimed at will have been entirely missed ; the object is to excite such interest in the subject as to drive the reader to the fountainhead—to the books the great master wrote.

---

[1] See L. Huxley, *Huxley's Life and Letters*.

The Origin of Species was published in 1859. The way for it had been to a considerable extent prepared by Charles Lyell's *The Principles of Geology*, wherein the author had argued that the earth's crust had assumed its condition not as a result of great catastrophic changes that had occurred from time to time, but as the effect of changes that had always and continuously been in progress, were in progress then, and would go on acting until the end of time—slow mutations not noticeable except in their cumulative results. This evolutionary theory, as it is called, was not new. Matthew Arnold, we are told by Dr J. W. Judd, expressed surprise that scientific people should make ' such a fuss ' about Darwin : " It's all in Lucretius," he said, and argued that Lucretius was the greater, because he divined that for which it took Darwin a lifetime to grope. The evolutionary idea had been in existence for thousands of years, but Lyell *proved* the truth of its application to the inorganic world and so led to Darwin's applying it to the organic world and proving its application there. By a startling coincidence Darwin was not alone, and the conclusions to which he was forced by his investigations had also occurred to Alfred Russel Wallace, while he was lying sick at Ternate in the North Moluccas. We are concerned here more with what they propounded than with the men themselves, but it is a fascinating story and one that teachers may usefully employ in dealing with moral instruction—that of the loyalty of these two men the one to the other. Although they reached almost identical conclusions and coined several phrases absolutely or almost identical, each gave to the other the full credit for his work and refrained from any attempt to exploit it for himself. We know that the discovery by Darwin that Wallace had conceived similar views simultaneously, and had actually got ahead of him in putting those views on paper, was a veritable shock for him. One of the noblest acts of unselfishness on record is Wallace's statement that his contribution to the new thought as compared with Darwin's was one week to twenty years, whereby he attempted to divert from himself almost the whole of the *kudos* that belonged equally to himself and to Darwin. It is an example of altruism that savours of another age, rather than of the competitive nineteenth century.

Nothing can detract from the brilliancy of their discovery, but the theory was itself evolved, and it must be understood (as has been indicated) that others had gone before and prepared the way. Two thousand years previously the idea existed that both inorganic and organic matter had been evolved, but it had been left to nineteenth-century scientists to prove it, and what Lyell and his fellow-workers had proved of inorganic matter undoubtedly smoothed the path for Wallace and Darwin. We say " smoothed the path " ; indeed, it needed some smoothing, because nothing of value could very well be known as to the origin of and changes in matter until the nature and properties of matter were to some extent understood. And it needed smoothing, too, for the sake of men's minds, because the nineteenth century was no more tolerant than was any other, though it was possibly more merciful than any of those that marked the beginning of modern times. Although religion was then, perhaps more than it has ever been in England, a matter of outward observance, it needed a bold man to face a people and say, in effect, that Genesis was an allegory and that God had really made the world in a much more remarkable manner than had been supposed, and, in consequence, that His greatness was even more stupendous than the mind of man had ever imagined. While every effort was made to discredit and ridicule the new idea as to the origin of things, the investigations that had been made into the origin of inanimate matter had certainly done much to make Darwinism acceptable to ordinarily instructed minds and, as we now think in the light of fuller knowledge, made its acceptance inevitable.

Darwinism, or Wallacism we might equally well write, is the doctrine regarding " the origin of species by descent with modification." In simpler language we may say that it teaches that the different species of animal and plant have arisen from a common stock ; if we followed back the ancestry of any existing organism we should notice slight differences tending toward simplicity of structure from generation to generation ; if we traced back the ancestry of two or more different types of organism we should find that they converged—as they became simpler in structure they resembled one another more and more until they met among the simplest forms in which we imagine life can be manifested. In an endeavour to be clear we may trace the origin of species forward as well as backward : the earliest forms of life were extremely simple, but each succeeding generation differed slightly from its parents and among themselves ; these differences, which were in the direction of complexity, were transmitted in an increased measure to the offspring, and by them to their offspring, and so on, until the differences were so great as to account for species, of which it is estimated there are now about 300,000 among animals alone.

Prior to Darwin the French officer Lamarck had, as it were, stumbled on to the truth, or a part of it, regarding these matters ; but Darwin had observed and studied as well as thought about them. Lamarck had got upon the track, but had strayed on to a by-path that led to a wrong conclusion—the conclusion that what are known as acquired characteristics are transmitted to the offspring. He thought that the long-necked giraffe had been evolved from a deer which during its life had, by practice, succeeded in so stretching its neck that it was able to browse off the more succulent herbage of trees ; that its offspring had inherited its parent's lengthened neck and had continued the process by stretching, and so on from generation to generation until the giraffe as we know it to-day had been produced. Lamarck was near the truth ; he recognized that different species had been produced from a common ancestor ; but because his ideas were not tested by actual observation he failed to show how they had been produced, and in trying to account for it he formed a conclusion which is now generally regarded as wrong. Had he attempted to test his ideas by personal investigation into the question whether acquired characteristics were transmitted, he would almost certainly have found that they were not, and he might have sought, perhaps successfully, the real facts that were lying behind his theories. We believe at present that characters acquired during the life of an organism are not transmittable to its offspring, and, so far as we can tell from experiments on other organisms, an eight-fingered race of men would never be produced by amputating the little fingers of every baby that is born. A deer or a pair of deer that had by effort elongated their necks would produce deer with necks no longer than the normal. It is, however, only fair to state that many French biologists—Cuenot, Giard, Perrier—think otherwise, and Kammerer in Austria claims to have proved that certain acquired characters can be and are transmitted, though he appears so far to have experimented only with organisms which we believe to be in a transitional state.

It is a fact that Nature is, in our eyes, very wasteful, and produces many more individuals than are destined to survive and to take part in the propagation of the race. No one who has seen the ditches and ponds full of frog spawn or teeming with myriads of black tadpoles can fail to appreciate what it would mean if they all grew up into mature frogs, all of which paired and produced young in their turn. The elephant, which reproduces itself more slowly than any other animal we know, would in a thousand years devastate the whole earth if every pair lived to breed throughout the whole of their active life; and amazing facts and figures have been offered regarding the humblest of animals—figures that are meaningless because they are bewildering in their immensity. Now of the countless numbers produced by the pairing of certain organisms no two are exactly alike, and, tiny and apparently insignificant as the differences are, we know that they have a significance to the individuals themselves, and that they sometimes mean the difference between success and failure in the fight for existence. Those differences are what lie below the expression ‘ the fight for existence,’ for the differences which tend to make some organisms more suited to their surroundings tend to preserve them to a period when they will reproduce themselves and launch upon the world young which will possess to a varying degree the helpful characteristics. To put the matter in another way, the conditions of life are always slowly changing, and the small differences exhibited by a brood of the young of a pair of animals will either make them more or less suited to the conditions in which they find themselves ; those which are less suited will not be so successful as those which are more suited. But notwithstanding the existence of small differences the offspring of organisms bear a remarkable likeness to their parents and inherit the characteristics that are bad as well as those that are good. We can discern a cumulative effect—the weaker or less fitted to their surroundings tend to disappear, while the others live, possessing not only the helpful qualities of their parents, but also—some of them, that is—helpful differences which their parents did not possess. When the facts of inheritance were less understood it was supposed—nay, rather believed as part of a religious creed—that every species, that is to say every kind of organism that differed from any other kind sufficiently in colour, shape, or size, was the subject of a special creation at the beginning. Now we know that all the different species of any animal or plant have been evolved from a common type by the process of small variations hardly noticeable from generation to generation in most cases, but sufficiently important in time to give rise to new species. This, in short, is what Wallace and Darwin discovered. Their discovery has given rise to a new school of thought and has profoundly altered man's attitude toward many questions, especially his attitude toward his own kind. Although, as has been observed, Darwin did not originally apply his arguments to man himself, it was quickly seen that it was impossible to escape that application. We cannot avoid the conclusion that, in the same way that a plant that inherited and passed on to its offspring a tendency to bear thorns and so discourage the onslaughts of browsing animals, so a man who inherited the tendency to size and strength and passed it on to his offspring would be likely to give rise to a strong and therefore successful race ; or that at a later stage in time the inheritance by a man of a larger or more efficient brain would give him advantages over his fellows which he would not be likely to waste, ' feathering his nest,' acquiring more of his needs with less effort, proving more successful in procuring food and obtaining and retaining shelter. And since the development of an active brain soon proved more important than the development of muscular strength and agility the organisms, particularly man, which developed it were able more than to hold their own in the world : the progeny of the more ' brainy ' men not only triumphed over less intelligent animals, but over less intelligent men.

Only now have we reached a stage when the bolder among us are asking publicly whether we have a right to ignore the knowledge we have (and which we make use of in breeding our wheat, poultry, and cattle) in breeding our own kind. Only now are those who have studied these matters deeply coming forward and suggesting that it is a crime to allow human beings with diseased brains and bodies which they will transmit to their offspring to marry and propagate a race of unfit persons. Owing to the artificial conditions in which we live Nature is not allowed to work as she does when she is left to herself and to eliminate the unfit, who, in competition with the fit, would fail to get mates, food, or shelter and would therefore in the end die out. The unfit of various kinds, suffering from diseases which we know—thanks to the investigations of Darwin, Wallace, Mendel, Weismann, and others—can be transmitted to their offspring are protected, housed, clothed, and fed, often directly at the expense of the fit and always at their expense ultimately, and rightly so ; but they are also allowed to marry and, as is so often the case, to produce large families doomed to similar unfitness and destined to crowd out the hospitals, prisons, workhouses, and lunatic asylums ! Pious but short-sighted, well-meaning but ill-instructed, people ask, " And why not ? What right have we to interfere in the free will of our fellows ? By what authority do we take into our hands the right which God has given to every one of us to order his own life ? And how can we limit God's power to right things in His own good time by His own means ? " Surely the answer is not far to seek. We do not hesitate to confine in hospitals and prisons those whose bodies and minds are so warped as to make them an immediate menace to us who, because we are in a majority, we call ' normal.' When our immediate good is concerned we are quick to act as custom and common sense dictate. Why, then, should we act differently when the evil is latent, but certain in the future to break out and demand action from our descendants ? And as to interference in the prerogatives of God, surely in revealing to us the facts of inheritance and giving us men of intelligence to perceive and interpret them He is inviting our co-operation quite as clearly as He was when He revealed to Harvey the circulation of the blood and to Lister the principles of antiseptic surgery. Would it not be as reasonable to assert that He allows pain to exist, that it is His will, and that it is therefore unjustifiable to make use of our knowledge of anæsthetics ? It seems inevitable that we should at no distant date apply our knowledge of the facts of inheritance to ourselves and set ourselves toward the goal of an efficient race of human beings. We have so far confined our efforts to the production of efficient strains of wheat, cart-horses, apples, sheep, milk-producing animals, cabbages, and other cultivated organisms that provide us with food and do our work, and are selecting and breeding from those only which possess the desired characteristics. Are we not bound at least to eliminate from the rights of procreation those of our own kind who possess undesirable characteristics which experience shows will be handed on to their unfortunate children ?

We cannot safely ignore the fact that while man, a real animal, though something more than an animal, is subject to the operation of natural laws that plants and other animals are subject to, the operation of those laws is continuing to modify him. But we know that he has taken steps to modify the operation of those laws so far as domestic animals and plants are concerned, and is limiting some of those powers over them and over himself and exploiting others. The laws are in operation even though he take steps to modify their effects. The rain wets him, the winter destroys his food-supplies, but he protects himself by umbrellas and waterproof clothing, and garners his crops in time and stores them where they will not be rotted by moisture or disintegrated by frost. Among the great untamed, the plant and animal world at large, it is different. The rain descends upon them, and only those best fitted to endure wet coats unharmed survive ; the frost seizes everything, and only organisms that have acquired a power to resist it can carry their activities into another summer. Animals and plants that cannot survive the temperature of winter have learned to shed their eggs and seeds—which are more resistant than they are themselves—to lie dormant in the earth throughout the winter, or themselves to suspend their animation sufficiently to be able to lie quiescent in such snug quarters as are available. So we find that the majority of perennial plants die down to their roots, which, protected by a covering of earth, sleep through the winter, while some animals that do not produce eggs in the autumn rest throughout the winter months, as, for example, the dormouse (*Muscardinus avellanarius*) and many insects ; a privet hawk caterpillar chooses the autumn for pupation, lying immobile until the warmth of early summer calls forth the perfect insect, and certain butterflies—the tortoiseshells (*Vanessa urticæ* and *Vanessa polychloros*) and the brimstone (*Genepteryx rhamni*), for instance—have learned to find warm corners in which they can resist inclemency of weather. All these devices have been developed by processes of natural selection. So, too, can we account for protective resemblance, which has been referred to in Chapter XIV. The buff-tip moth (*Phalera bucephala*) resembles, when at rest, a broken piece of birch-twig ; the fact that all buff-tip moths continue to resemble pieces of birch-twig can hardly be accounted for except on the hypothesis that at some time there arose moths which tended to such a resemblance, and that they secured considerable protection therefrom, so much so that they were able to propagate their kind successfully and became widely established. And their success is sustained to-day ; they are firmly entrenched behind this protection, which is not afforded to generations that deviate from the approved pattern ; the disguise of such is detected, and many of them fall a prey to their enemies. Changes are still in operation, and those that diminish their resemblance to the twig they simulate are all to their disadvantage; those that make their resemblance greater, or tend to make them like other things secure against molestation, are to their advantage, and increase their prospect of perpetuating their kind, who will resemble their parents and perhaps in the cases of individuals carry the resemblance a step farther toward perfection.

CHAPTER XVI

SOME PRIMITIVE ANIMALS AND PLANTS

NOW that we have inquired into the theory of descent with modification we may with advantage consider the quality of primitiveness possessed by certain plants and animals. We frequently use the word ' primitive ' of both plants and animals, meaning ' simple,' but in the sense in which we propose to use the word in this chapter we do not necessarily mean simple; indeed, the organisms to which we shall refer are not simpler than others, neither are they primitive if the word is assumed to mean that they resemble types that were in existence in geological ages long past. They have been subject to modifications as important as those to which other organisms have been subject, but, for reasons for which we cannot completely account, they have retained certain characteristics which we are forced to believe were possessed by ancestors from which both they and their more ' modern ' fellows have been evolved. When we refer to Amœba and Protococcus as primitive we do not necessarily mean that the earliest forms of animal and plant resembled them in shape, or that their structure was equally complex or equally simple. We mean, in these particular cases, that they feed and reproduce themselves much in the manner that we suppose the earliest forms of life did. We can hardly imagine that the earliest green plants and the first indubitable mammals bore a striking resemblance to the bracken fern and the kangaroo, both of which, nevertheless, possess some primitive features. Their primitiveness lies in their methods of reproduction—the bracken fern by its employment of spores, the kangaroo by the presence of a pouch and the absence of the special provision for the nutrition of its young prior to birth which is made by the majority of mammals. Nevertheless, the kangaroo is not an animal that has stood still while the rest of the organic world marched along the road of progress and development. We cannot enter into all the details now ; although there is every reason for regarding the pouch as a primitive characteristic, there is ample evidence that other so-called primitive features of the kangaroo, and of the marsupials generally, are the result of retrogression—they have lost their higher characteristics, and their reproductive processes have degenerated in important respects.

Any attempt to sketch a rough idea of the lines upon which evolution has worked would be unsatisfactory, because so many of the links in the chain are missing ; either they have been destroyed or they have not yet been unearthed. But as discoveries are still being made—and amazingly valuable evidence has come to light during the sixty years that have elapsed since Darwin and Wallace gave us the code by which we could interpret them—he would be unduly cautious who chose to adopt the former view.

We have suggested reasons [1] for supposing that life was originally manifested in a green plant, and many believe that it first appeared in the sea. Numerous conclusions point to the probability that simple algal forms, motile and free-swimming, preceded the ordinary green plant with its specialized tissues. A free-living, single-celled organism is clearly well adapted for such a simple manner of life as we suppose the ancestors of our modern plants practised, for with them, as we know, water-supply is often a difficulty. Many of the modifications with which we are acquainted are the outcome of attempts to make income and expenditure balance, generally by the limitation of expenditure, because they can exercise no control over income. A single-celled plant swimming freely in and completely submerged by water would experience no difficulty of this nature. As soon as plants migrated to the land they were confronted with the water difficulty, and in most cases they solved it by the development of absorptive roots, which they thrust down into the earth or into the tissues of their hosts—and the modifications to which reference has been made indicate that they have not always found all they required. Such a change as that from water to land imposed, it must be observed, a fixed habitat, for the roots could not be withdrawn and re-established without the almost certain result of desiccation and death. The importance of these observations will be appreciated when we have considered the life-history of the bracken fern, to which we referred in Chapter XI.

---

[1] See Chapter X.

The bracken fern (*Pteridium aquilinum*) is one of the most widely distributed plants, and it grows most frequently on dry, often sandy, commons, sometimes far removed from water. We know that it is propagated by means of spores. It does not produce flowers, and it is alleged that it seldom makes use of its spores ; it travels, and it is a great traveller, by means of its perennial underground root-stock. But the bracken fern possesses a potential means of reproduction in its spores, which are produced in countless, bewildering numbers, each of which in suitable conditions can give rise to a new plant. The process was referred to when the subject of alternation of generations was considered, but the object we have in view in now referring to it is to emphasize the fact that the existence of water is necessary to make it possible that any spore does in fact fulfil its destiny. Drought is necessary that the spores may ripen and be distributed ; once shed they may be carried enormous distances by the wind, and in view of their number the plant is enabled to spread itself over a wide area that it could not possibly conquer were it dependent upon its creeping root-stock. But the majority—indeed, almost all—of the spores are doomed to perish, for abundant moisture is essential to their development. The climate of this country does not encourage the spreading of ferns, which require warm and very damp conditions in most cases for their propagation. We shall later suggest reasons for regarding the ferns, and organisms that reproduce themselves as ferns do, as plants that have not completely adapted themselves to a terrestrial life ; one cannot rid oneself of the thought that if they had the same power of movement as is possessed by some plants and animals

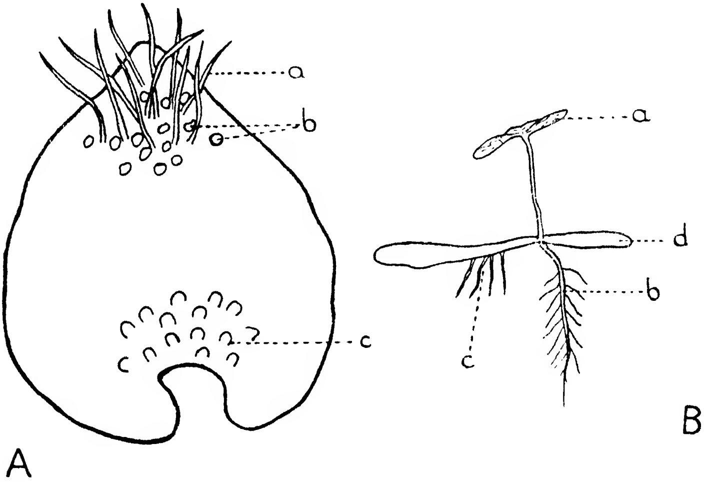


Fig. 23.—Fern prothalli. A. Prothallus seen from below. (*a*) Root-hairs. (*b*) Antheridia. (*c*) Archegonia. B. Young fern growing from prothallus. (*a*) First leaf. (*b*) Root of young fern. (*c*) Root-hairs of prothallus. (*d*) Prothallus.

ferns would, like frogs and toads, betake themselves to the nearest pond for the breeding season.

However, any spore of the bracken fern, or of any fern, that finds the water and sufficient warmth will grow into a flat, heart-shaped body known as a prothallus, deep green in colour, which lies flat on the ground or in whatever cradle has been destined to receive the young plant. The prothallus is self-supporting in that it possesses chlorophyll and roots, but it is of frail texture and needs a continuous supply of water to maintain itself, and any setback in this respect involves its death. If, however, conditions favour it there are produced on its under side antheridia and archegonia, male and female organs respectively, each of the former developing a number of sperms and each of the latter a single ovum. When they mature and come into contact with water, generally by the fall of rain, the sperms are discharged into the water which has accumulated between the earth and the under side of the prothallus, and in this water they move about by lashing their cilia. The ovum is not discharged into the water ; it remains in the archegonium all the time, but a channel to the ripe ovum is opened. Provided the water-supply is adequate a sperm makes its way to the ovum, attracted by a substance given off by the archegonium, moving from the weaker solution of this substance in the surrounding water to the stronger solution within the organ itself. A union is thus effected, and the ovum becomes a fertilized cell, which develops into a young fern plant, living first upon the substance of the prothallus and later growing roots for itself and becoming a perfect bracken fern.

Can we well avoid the conclusion that the life-history of the bracken fern epitomizes in a general way the history of the evolution of the ordinary land plant ? It is, as we have observed, a plant that has a long history behind it ; many fossil types resemble it closely. We believe that plants originated in water—either in the sea or in lakes or swamps—probably as motile organisms ; we know that for its spores to develop and fulfil their destiny a supply of water sufficient for the sperms to swim in and reach the ova is necessary. The interest the plant has for us lies in the fact that at one stage it is dependent upon conditions in which we believe plants originated, while at all other stages it exhibits a characteristic that we have reason to think was at one time associated with all land plants—the propagation of its kind by the production not of flowers and seeds, but of spore capsules and spores.

We can now proceed to a consideration of the spore-producing organ and its relation to the seed-producing organ—the flower.

The horsetail (*Equisetum*) is commonly met with in most parts of the country, frequently forming fairy-like forests at the margins of ponds, but sometimes establishing itself in fields and by roadsides where the amount of water is much restricted. There are several species in this country, some of which seem to need a moist habitat, but others can withstand a considerable amount of drought. Their stems resemble straw, but they bear whorls of leaves that are hardly larger than small hairs. Although they do not, as a rule, attain a height of more than two or three feet, measured from their junction with the underground root-stalk to their tips, and are often much smaller, on some parts of the globe they reach a considerable height. In remote ages—the Mesozoic, during the last period of which, the Cretaceous, our chalk downs were deposited and birds began to appear ; and the Paleozoic, which ended with the Carboniferous period, in which our coal was laid down and the first terrestrial vertebrates arrived on the scene—they and their relatives attained a considerable size and were often over thirty feet in height and several feet in circumference. Even to-day one British species (*Equisetum maximum*) is occasionally met with growing to a height of six feet. So far as their structure and habits can be ascertained, these ancient forms resembled closely those we have with us now ; it has been suggested that a grove of them growing in their native swamps in Carboniferous times viewed through a pair of field-glasses reversed would have looked very similar to those we may find growing at the edge of an English pond. Fortunately most of us have access to this plant, and, even though we may not be able to find it in the immediate neighbourhood of the school, we can as a rule without difficulty secure specimens that will serve our purpose. If we examine them in spring or early summer we shall observe that the stems are of two kinds ; the majority are obviously nutritive only, bearing their fine, green leaves and nothing else ; but others stand out conspicuously, because, though their leaves are not so well developed, the ends of the stems bear cones of a yellow hue which change at their tops to brown and red. If we shake the stems when the cones are ripe a fine dust will emerge from the cones. If the dust is pollen, where are the female flowers it is destined to fertilize ? Instinctively we decide that the cone is not a perfect flower—it does not conform to any of the descriptions of a flower with which we are familiar. So we are forced to the conclusion that the dust from the cones is not pollen, but spores. Into the minute structure of the plant we need not enter, though the teacher will find it a valuable subject for a lesson. It is desired only to draw attention to the two kinds of stem—those engaged in vegetative duties only and those that have been modified, so far as their vegetative duties are concerned, and have specialized on the function of reproduction. They bring us to a consideration of the question to which we referred in Chapter VIII—the

XVI. Marsh Horsetail (*Equisetum palustre*), showing Nutritive and Fruiting Shoots

Photo H. R. Royston

origin of the flower, which, it has been suggested from time to time, is nothing but a metamorphosed leaf.

Let us examine the theory in the light of the methods of reproduction adopted by ferns, club-mosses, and horsetails—all plants that possess something in common with the predominating plants of earlier times. Although they have doubtless been modified in other respects since the time flowers first came into existence, their methods of reproduction remain in all probability much as they were then. Most mature ferns—let us instance the ordinary male fern (*Nephrodium filix-mas*)—bear spore cases, or sporangia, on all their leaves, the whole of the foliage of the plants serving the dual purpose of providing for vegetative growth and reproduction. But there are some ferns—the hard fern (*Lomaria spicant*) is one—that produce definitely vegetative and definitely reproductive foliage, though it must be understood that in no sense whatever can the reproductive leaves be regarded as flowers, for they produce spores, and not seeds. The fir club-moss (*Lycopodium Selago*), a common British species, produces at first only vegetative foliage, but after a time the stems as they grow develop sections that bear spore cases, and sections that serve a solely nutritive purpose, and these sections alternate. In the areas of transition there are imperfect spore cases ; the sections are not exactly defined, but they are alternate as parts performing two different functions respectively. It seems a fair presumption that this condition was evolved from a condition in which we now find the male fern, and that the club-moss found that some good purpose was served by specialization. Other club-mosses develop spore cases only at the ends of their stems, while the horsetails, as we have seen, produce reproductive organs at the ends of specialized fertile stems only, the majority serving merely a nutritive purpose. The suggestion is that at one time every stem bore sporangia, and that prior to that period the whole of the foliage was fertile, as the foliage of the male fern and the bracken fern still is. We are led to think that the flower was not evolved by the modification of vegetative leaves, but that vegetative leaves were evolved not actually from flowers, but from organs that served the purposes both of providing food for the plant and propagating its kind. While this does not take us very far in the direction of the discovery of the origin of flowers, we are at least fortunate in the possession of fossil forms of the seed-producing organs of certain plants resembling in other respects, and suggesting even in this, existing cycads, a group to which the sago-palm (*Cycas revoluta*) belongs. These have enabled botanists to trace the probable origin of the production of seeds by flowers, and afford us much reason for supposing that flowers have been metamorphosed from cones not dissimilar from those borne by the horsetails. In these fossil remains are evidences of an ovule-bearing organ, which, like the stamens that surround it, may quite well have had its origin in a cone that had been developed from an aggregation of fertile leaves.

Our sketch of the development of the modern flower is, therefore, almost as complete as we could hope to make it, and seems conclusively to indicate that far from flowers having originated from leaves, or rather reproductive areas from vegetative ones, the reverse is more likely to have been the case, and leaves have been developed from fertile areas. More accurately we may say that the evidence we have points to the probability that vegetative leaves have arisen from dual-purpose foliage—have, in fact, become sterilized so that they might concentrate more fully upon their function as nutritive organs. It seems to be a case of specialization, the advantages of which Nature found out long before the Industrial Revolution. Man in specializing in his work has made it more mechanical and less interesting; but he has reaped in increased production an advantage which he will appreciate more as education enables him to wrest from his leisure hours the joys that come from a wider view of life and an increased interest in things that are not mere factors in production. Plants, too, paid a penalty when they set apart certain of their areas to concentrate upon their nutrition and others to give their whole energy to reproduction; they lost in many cases their vast, almost incredible, fecundity; but they gained the advantages of cross-fertilization, which led to the infusion of new blood, an increased robustness, and greater variety. That the change has been justified by its results can hardly be questioned, because there appears to be no tendency to go back to the old system. Some observers have seemed to distinguish a tendency in this direction in the large amount of self-fertilization that undoubtedly takes place among plants, but, unless it can be shown that such plants are exhibiting an increased tendency to self-fertilization, it does not appear probable that reversion to a flowerless earth is at all imminent.

Though the plants to which reference has been made bear so striking a resemblance to some of the plants that flourished in the long-distant past, they have doubtless been modified in some important respects during the course of their descent. In describing them as primitive we mean that they exhibit certain features which were exhibited by plants of long ago, and the chief of these features is their method of reproduction, which in times past was as general as the flowering habit now is, but is now confined to comparatively few plants. We are bound to be less confident in specifying the modifications that have taken place since those days. There seems reason for conjecturing that the habit of propagation of the bracken fern by means of a creeping root-stock is a modern acquisition ; it is not common among ferns, but is frequently met with among the higher plants. The success of the bracken fern has been due to its ability to adapt itself to every imaginable habitat, provided it has soil of some kind. Unless it had developed an alternative method of establishing itself it could not have made its way into tracts of country where the soil is sandy, hot, and dry, because it can not reproduce itself by means of its spores in the conditions there obtaining. Horsetails and club-mosses, on the other hand, seem to have adapted themselves to modern conditions by diminishing their size, though we cannot be sure that small forms as well as large did not exist in the coal forests.

When we come to consider animals we find disturbing gaps no less important than those between the flowering plants and the non-flowering plants, but in their cases also fresh light is constantly being afforded by the investigation that is being made. Were it not so we should not with any certainty be able to decide whether the unusual characteristics exhibited by some animals are advances upon the normal type. It is only by taking a very wide view, not only of the present but of the past, that we are able to interpret what we find. When we attempt to show how one group of animals or plants is connected with another, and how their differences were evolved, we constantly encounter questions which can be answered only by intelligent surmise ; to give an example, one of the biggest gaps zoologists of years ago were faced with was that between the worms and the animals possessing jointed appendages. Worms, we know, possess feet, but their feet possess no joints, and the absence of any apparent connecting link long puzzled zoologists. As a matter of fact, it was not the origin of jointed limbs that they were so much concerned about, but important differences in internal structure. The discovery of an animal somewhat resembling both a caterpillar and a centipede provided the link required. The animal in question, known as Peripatus, has a very much restricted distribution, and is believed to exist only in Tasmania, New Guinea, the Malay Archipelago, and parts of South Africa, South America, and Australia. In accordance with our practice of avoiding so far as possible the details of organisms other than those which can be easily obtained and suitably introduced to the home or the school, it seems desirable not to dwell upon this animal ; but its importance is considerable, because its development does appear to bridge the gap that otherwise exists between the annelids and the insects, which it has long been thought have been evolved from them. It may justly be considered a primitive animal which has existed in an unchanged form (so far as some of its features are concerned) over a very long period of time.

Most people have heard of Echidna and Platypus, because the fact that they lay eggs instead of producing their young alive is generally cited as one of the paradoxes illustrating the peculiarities of antipodean life. Most grown-ups will recall that as children they were told that Australia is a country on the other side of the globe which has winter while we enjoy summer, darkness while we have daylight, cherries the stones of which grow outside the fruit, swans that are black, birds that never sing, and—' animals ' that lay eggs. Except for this most of us know but little of either Echidna or Platypus. Yet they possess features that stamp them as being primitive, though here again we must bear in mind the probability that some of them are secondary acquisitions—that is to say, they have been gradually adopted as Echidna and Platypus have conformed to changing conditions of life. Nothing but confusion can arise if we overlook the fact that neither among animals nor plants do we find many cases of marking time while other forms of life developed and adapted themselves to changing conditions. There are living organisms which are believed to resemble very closely forms which are coming to light as fossils preserved from previous ages, but they are few. It is, of course, possible to imagine that a number of small organisms, cut off from contact with the outer world, might live on unchanged, having, as it is said, attained equilibrium with a localized and unchanging environment, but when such conditions are reached it is far more likely that degeneration will ensue.

Nevertheless, it would be unwise to belittle the importance of those primitive features that indicate beyond reasonable doubt that the ordinary line of mammalian development was deserted by Echidna and Platypus at an early period long before the existing processes of reproduction had reached their present stage. Examples of these two animals may be found in most zoological museums, and their external features will indicate even to the child, or the man or woman with no pretensions to biological knowledge, that they are highly specialized creatures, though they will not visibly link them up with the reptiles, from which mammals are evolved. Echidna, known also as the spiny or porcupine ant-eater, is commonly known in Australia as the porcupine and, in some districts, as the hedgehog, but it should not be confounded with either. There are two species : one (*Echidna aculeata*) is found in New Guinea, Australia, and Tasmania ; the other (*Pro-echidna bruijnii*) is confined to New Guinea. Both live upon ants, which they collect by means of a long and specially adapted tongue. They are covered by a mixture of hairs and spines, and when they have occasion to put themselves into a condition of defence they can roll up like a hedgehog. In both cases the snout is elongated and from above has the appearance of a bird's bill, the impression being heightened by the bead-like eyes. The limbs and powerful claws denote them at once as subterranean creatures accustomed to excavation in search of food and home, the latter being burrowed out beneath a rock or the roots of a tree. Platypus, or Ornithorhynchus, commonly known as the duck-mole, or duck-bill, is found in Australia and Tasmania, and there is only one species (*Ornithorhynchus anatinus*). It is amphibious and frequents the banks of rivers, living very much like a duck on molluscs and any higher forms of aquatic life that fail to evade it. It resembles a duck in other ways, for it is furnished not with the kind of mouth we associate with mammals, but with a flattened bill of horn, which it uses exactly as does the duck, and with webbed feet, which make it an efficient swimmer. Its bill is a very sensitive organ of touch, and notwithstanding the webbing its feet are provided with strong claws. It bears dark brown fur, dense and smooth like that of the otter, and it should be observed that such furs are usual among amphibious mammals; they resist the water because the hairs imprison air, which acts as a defence against both the wetness and the coldness of the denser medium. Any detailed description of these animals would be superfluous, and those interested cannot be too strongly urged to pay a visit to a museum possessing specimens, for stuffed ones will serve to show the points to which reference has just been made.

But it is with their methods of reproduction that we are specially concerned in dealing with Echidna and Platypus. Although they suckle their young, and are therefore true mammals, they do not fulfil the other condition usually regarded as characteristic of mammals; they do not produce their young alive—that is to say, in an advanced state of development, having the appearance of their parents in miniature.

They come into the world as eggs ! And these eggs are more like reptilian eggs than those of birds. Only one egg is produced at a time, and it is separately hatched, Echidna placing its egg in a pouch that forms only at the breeding season and, when it has served its purpose, disappears again. The egg of Echidna hatches, and discloses a very tiny animal, which remains in the pouch and obtains its sustenance from the much modified mammæ, which exist in close proximity to the opening of the pouch. Platypus hatches its egg in a nest of grass and sticks, and the young animal is reared there, suckled by its mother until it is sufficiently grown to seek food for itself.

A great part of the interest these animals possess for us lies in their primitiveness, but we must be careful to ensure that we recognize their truly primitive features. As has been remarked, in some respects Echidna and Platypus are very highly specialized animals, and we must regard their curious mouths not as primitive features linking them with birds, but as secondary acquisitions fitting them for a special kind of life. And similarly with their digging limbs and webbed feet. But when we regard their method of reproduction, details of their skeleton, the smoothness of the brain, the presence of a cloaca instead of separate openings for the rectum and the urinogenital organs, we cannot avoid the conclusion that we are dealing with characteristics which quite possibly—indeed probably—have been retained from a time prior to the origin of their mammalian features, and which link them up with the reptiles from which they are sprung.

Primitiveness is a subject that has its limitations as one for school instruction, but some reference to primitive animals and plants seems a necessary complement to the consideration of Darwinism, and at least it is of importance to the teacher for a variety of reasons. If we were able to do here what it is earnestly hoped the interested teacher will find time to do—follow up this subject—we should most certainly discover that the doctrine of descent with modification does not indicate progress, as we understand the word, all along the line. We are liable to regard evolution as always involving progress, and we have been reminded that conditions of stagnation and degeneracy sometimes intervene. At the present time a large proportion of humanity has successfully removed itself from the operation of natural selection, so far as bodily strength and dexterity are concerned, while man's so-called mental activities and his culture are largely matters of custom, taste, or fashion, to which the processes of selection apply only to a limited extent. 'The progress of the human race' generally means only progress in arts and taste, which, it has been pointed out to us, depend upon continuity of tradition, and we have quite recently seen what happens when a set of conditions arises that breaks, even temporarily, that continuity; we have seen enough to draw intelligent conclusions as to what would happen were that continuity to be seriously broken. Man aims at creating his own environment and at circumventing the operation of natural selection, and we know what may happen among plants and animals which create their own environment, because when we were considering the subject of parasitism we found that simplification and degeneracy were the rule. Improvements that endure, we know, are the result of the inheritance of a capacity for advancement, not merely of a desire to advance, and it may be that progress is continuous along these lines. Nevertheless, we are bound to recognize the possibility (it would probably be unwise or unduly pessimistic to use a stronger word) that the capacity for advancement may be interrupted or, as has probably been the case with many extinct organisms, completely lost. There may be among any particular group of animals or plants a capacity to progress—that is to say, to continue to adapt itself to changing conditions, or there may be a failure on its part to adjust itself to those changing conditions, involving extinction. We have referred to the existence of types that seem to have persisted from time immemorial, suggesting that a stage of equilibrium with Nature may be reached, and that a type may remain unchanged, neither progressing nor retrograding over vast periods of time. It may be that man has reached that stage now, as the marsupials of Australia had before civilized man discovered that continent, or he may even be degenerating. Some there be who think a discovery may be made that will prove that civilizations equal or superior to that of Western Europe existed in times long past, and there are reasons tending in part to substantiate such views in recent discoveries of ancient civilizations. Some persistent types have been adduced, both plants and animals, and it may yet be found that man has again and again attained a high degree of culture which has as often been swept away as he failed from time to time to control both his own kind and his other environment.

INDEX

ABIOGENESIS, 191
Accretion, growth by, 25
Æsculus hippocastanum (horse-chestnut), Pl. IV
Air, composition of, 65, 66, 69, 72
Air bladder of fish, 166
Air sacs of the lungs, 85
Algæ, 34, 38, 200, 220, 221, 222
Ammonia, 194
Amœba, 39 *et seq.*, 192, 194
Amylopsin, 84
Anabas scandens (climbing perch), 169
Anemone, sea, 183
Annelidan theory, 206
Antheridia, 262
Anthers, 105, 114, 115, 118
Anthocyanine, 149
Aphides, 203, 204, 205
Archegonia, 262
Arnold, Matthew, 247
Arteries, 89 *et seq.*
Artery, pulmonary, 85
Asterias rubens (starfish), 170, 171, 172
Auricles of the heart, 88
Auriculo-ventricular valves, 90
Axil, leaf, 50, 102

BACTERIA, 32, 193, 194, 195
Bacteria trophinus (stick insect), 240
Barbs of feather, 159
Barbules of feather, 159
Bathybius, 191
Beech (*Fagus sylvatica*), Pl. XIII
Bees, conveyance of pollen by, 118, 119, 125
Belgian hare, 79
Bile, 83 ; duct, 84 ; sac, 83
Biogenesis, 191
Birds, 157 *et seq.* ; relationship to reptiles, 160
Biston betularia (pepper moth), 240
Bladderwort, common (*Utricularia vulgaris*), 227
Blastoderm of egg, 107
Blood, mammalian, 83 ; circulation of, 88 *et seq.* ; composition of, 86 ; corpuscles of, 86, 87
Bracken fern (*Pteridium aquilinum*), 202, 258 *et seq.*, Pl. V
Brain, mammalian, 96 *et seq.* ; grey and white matter of, 97
Brenchley, Dr W. E., 59
Brimstone butterfly (*Gonepteryx rhamni*), 256
Bronchi, 85
Buff-tip moth (*Phalera bucephala*), 256
Bufo vulgaris (toad), Pl. XII
Butterwort (*Pinguicula vulgaris*), 224

CALCIUM CARBONATE, 74
Calyx of flower, 112, 113
Canadian water-weed (*Elodea*), 70
Capillaries, blood, 84, 85, 89, 91, 92
Capsella bursa-pastoris (shepherd's purse), 48
Carbon, 65, 66, 69, 72, 73, 86, 195
Carbonic acid, 70, 71, 72 ; test for, 74
Carbonic acid gas, 65, 66, 69, 72, 75, 76, 85, 86, 87, 195
Carpenter, Mr G. H., 208
Caterpillars, 197
Catkins of stinging nettle, 153 ; of willow, 124, 125

Catocala nupta (red underwing moth), 238
Cell, division of, 35, 36, 37 ; structure of, 28
Cellulose, 31, 36
Centrosome, 36, 37
Cheiranthus cheiri (wallflower), 47 *et seq.*
Chlorophyll, 32, 33, 60, 63, 64, 72, 87
Chloroplasts, 32, 33
Chromosomes, 36, 37
Circulation of mammalian blood, 88 *et seq.*
Cladonia rangiferina (reindeer 'moss'), 222
Climbing perch (*Anabas scandens*), 169
Clitellum of earthworm, 180, 181
Club-mosses, 265
Clupea harengus (herring), 163 *et seq.*
Cnidoblast of hydra, 186
Cnidocil of hydra, 186
Cockroach, 203
Cocoon of earthworm, 181
'Cold-blooded' animals, 167
Colour, development of, in breeding season, 133 ; protective, 237 *et seq.* ; sympathetic, 237 *et seq.* ; warning, 237 *et seq.*
Combustion, chemistry of, 86
Contractile vacuole, 41
Convoluta, 26, 27
Corolla of flower, 112, 113
Corpuscles, blood, 86, 87
Cotyledons, 102
Courtship of frogs, 136 ; of sticklebacks, 113
Cratægus oxyacantha (hawthorn), Pl. III
Crop of bird, 161
Cross-fertilization, 119, 123, 125 *et seq.*, 235
Cruciferæ, 112
Cryptogams, 139
Cuenot, L., 251
Cuscuta (dodder), 212, 213, 214
Cycas revoluta (sago-palm), 266
Cygnus olor (swan), Pl. XI
Cypripedium calceolus (lady's slipper), 227

DANAID butterflies, 241
Darwin, Charles, 122, 176, 177, 228, 246 *et seq.*
Dead-nettle, white (*Lamium album*), 152
Desert flora, 150
Diatoms, 38
Dicranura vinula (puss moth), 239, 240, Pl. XIV
Digestion, process of, in birds, 161, 162 ; in mammals, 81 *et seq.*
Dionæa muscipula (Venus' fly-trap), 226
Dodder (*Cuscuta*), 212, 213, 214
Dormouse (*Muscardinus avellanarius*), 256
Drosera rotundifolia (sundew), 225, 226
Duck-bill (*Ornithorhynchus anatinus*), 271

EARTHWORM : *Lumbricus herculeus*, 176 ; *Lumbricus terrestris*, 176 *et seq.*
Echeneis remora (sucker fish), 234
Echidna aculeata (spiny ant-eater), 269, 270, 271
Echinodermata, 170
Eel-grass (*Vallisneria spiralis*), 127, 128
Egg, bird's, structure of, 105 *et seq.*, 160 ; frog's, 106, 136, 197 ; snail's, 173 ; snake's, 106 ; stickleback's, 134
Elodea (Canadian water-weed), 70
Emberiza citrinella (yellow-hammer), nest and eggs of, Pl. II
Embryo of chicken, 107, 108 ; of pea, 102
Equisetum (horsetail), 263, 264
Equisetum maximum, 264

INDEX

Equisetum palustre (marsh horsetail), Pl. XVI
Esox lucius (pike), 235
Euchloe cardamines (orange-tip butterfly), 238
Euglena viridis, 26
Extensor muscles, 94, 95

Fagus sylvatica (beech), Pl. XIII
Feathers, 158, 159, 160
Fern prothalli, 126, 262
Ferns, reproduction of, 265 *et seq.*
Fertilization: of ovules of plants, 117 *et seq.*; of frog's eggs, 136; of hen's eggs, 137; of stickleback's eggs, 134; cross-fertilization, 119, 123, 125 *et seq.*, 235, 267; self-fertilization, 122, 125 *et seq.*, 267
Fins of fish, 166
Fir club-moss (*Lycopodium Selago*), 265
Fish, 163 *et seq.*; flat, 168, 169; 'flying,' 169
Flagella, 201
Flagellata, 201
Flat fish, 168, 169
Flexor muscles, 94, 95
Flight of birds, 159
Flowers, 53, 111 *et seq.*, 140; evolution of, 140; imperfect, 128; perfect, 122, 128; pistillate, 123, 153; staminate, 123, 153; structure of, 112 *et seq.*
'Flying' fish, 169
Frog, 197 *et seq.*; spawn of, 136, 137, 197
Fruit of pea, 101; of wallflower, 121; of willow, 125
Fungi, 220, 221, 222

GAMETOCYTES of malarial parasite, 218
Garden snail (*Helix aspersa*), 172 *et seq.*
Gasterosteus aculeatus (three-spined stickleback), 131 *et seq.*
Gastric juice, 83, 84; mill, 161
Giard, A., 251
Gills of fish, 164, 165, 198, 199, 208
Gizzard of bird, 161
Gnats, 215
Goethe, J. W. von, 149
Gonepteryx rhamni (brimstone butterfly), 256
Gorse (*Ulex europæus*), 142, 143, 144
Grass-snake (*Tropidonotus natrix*), 239
Grey matter of brain, 97

HÆMOCYANINE, 175
Hæmoglobin, 87, 179, 233
Hard fern (*Lomaria spicant*), 265
Harvey, William, 254
Hawthorn (*Cratægus oxyacantha*), Pl. III
Heart, mammalian, 87 *et seq.*; piscine, 165; valves of, 90
Helix aspersa (garden snail), 172 *et seq.*
Hen's egg, structure of, 105
Herring (*Clupea harengus*), 163 *et seq.*
Honey glands, 115, 123; sacs, 117, 123
Horse-chestnut (*Æsculus hippocastanum*), Pl. IV
Horsetail (*Equisetum*), 263, 264
Horsetail, marsh (*Equisetum palustre*), Pl. XVI
House-sparrow (*Passer domesticus*), 204, 244
Hover flies, 204
Huxley, Thomas Henry, 191, 246
Hyacinth, wild (*Hyacinthus nonscriptus*), Pl. V
Hydra, 182 *et seq.*
Hydra fusca, 186
Hydra viridis, 186
Hydra vulgaris, 186
Hydrocharitaceæ, 127

Hydrochloric acid, 83
Hydrogen, 70, 72

ICHNEUMON fly, 211, 212
Imperfect flowers, 128
Incubation of hen's eggs, 106 ; of stickleback's eggs, 134, 135
Infusoria, 44
Insects, 202, 203
Intestine, 83, 84
Intussusception, growth by, 25
Involuntary muscle, 96
Iodine test for starch, 65
Iron, 59, 63
Ivy, 144

JELLYFISH, 182, 187
Judd, Dr J. W., 247

KAMMERER, PROFESSOR P., 251
Kangaroo, 259
Kidneys, 93

LABIUM, 203
Lacewings, 204
Lacteals, 84
Ladybirds, 204
Lady's slipper (*Cypripedium calceolus*), 227
Lamarck, J. B., 250
Lamium album (white dead-nettle), 152
Larva of frog, 197 *et seq.* ; of insect, 206 ; of ulothrix, 201, 202
Leaf axil, 50
Leaves of plants, 49, 50, 52, 53, 54, 142
Lecanora atra, 222
Leucocytes, 87
Levers, bones and muscles as, 96
Lichens, 34, 220, 221, 222
Light, response of foliage to, 25
Lime, 59, 74
Lister, Lord, 254
Littorina littorea (periwinkle), 175
Liver, 83 ; circulation in, 91
Lomaria spicant (hard fern), 265
Lophinus punctatus (common newt), 244
Lucretius, 247, 248
'Lung' fish, 169
Lungs, 85, 88, 89, 90, 93, 166, 167, 199
Lycopodium Selago (fir club-moss), 265
Lyell, Sir Charles, 247 *et seq.*
Lymph, 83, 92, 93
Lymphatic glands, 92 ; system, 92, 93

MACROGAMETES of malarial parasite, 218
Macrogametocytes of malarial parasite, 218
Madreporite of starfish, 172
Magnesium, 59
Malarial parasite, 215 *et seq.*
Male fern (*Nephrodium filix-mas*), 265
Mammals, 77 *et seq.*
Mandibles, 203
Marsh horsetail—see Horsetail
Matthiola annua, 48
Maxillæ, 203
Medusa-buds, 187
Mendel, G. J., 254
Merozoites of malarial parasite, 217 *et seq.*
Microgametes of malarial parasite, 218
Microgametocytes of malarial parasite, 218
Micropyle, 101
Mistletoe (*Viscum album*), 145, 146
Mollusca, 172
Mosquito, 215 *et seq.*
Mucous glands, 85 ; membrane, 84
Mucus, 85
Muscle, 88, 93 *et seq.* ; extensor, 94, 95 ; flexor, 94, 95 ; involuntary, 96 ; voluntary, 96

INDEX

NATURAL selection, 133
Nectar, 117, 118
Nematocysts of hydra, 185
Nephrodium filix-mas (male fern), 265
Nerves, 88, 96 *et seq.*
Nervous system, mammalian, 96 *et seq.* ; of snail, 175
Nest of three-spined stickleback, 132
Nettle, Roman (*Urtica pilulifera*), 155 ; stinging (*Urtica dioica*), 151 *et seq.*
Newt, common (*Lophinus punctatus*), 244 ; great crested (*Triton cristatus*), 244
Nitrates, 194
Nitrites, 194
Nitrogen, 65, 72, 76, 85, 194, 228
Nucleus, 28, 35
Nymphæa alba (white water-lily), 147 *et seq.*, Pl. VIII, Pl. IX

OBELIA, 187
Oocyst of malarial parasite, 218, 219
Orange-tip butterfly (*Euchloe cardamines*), 238
Ornithorhynchus anatinus, 271
Ova of frog, 136 ; of stickleback, 134
Ovary, 105, 116, 120
Ovules, 103, 104, 116, 118, 120
Oxygen, 65, 66, 69, 72, 73, 86, 87, 89, 233 ; given off by plants, 70, 71, 88 ; test for, 70, 71 ; used by plants and animals, 74, 75, 76, 85

Paludina vivipara, 175
Pancreas, 83
Pancreatic juice, 83
Paramœcium, 43, 44
Parasitic plants, 64, 144, 145
Parasitism, 144, 145
Parental care, 162, 163
Parmelia, 220
Parthenogenesis, 204
Partridge (*Perdix cinereus*), hen, Pl. XV
Passer domesticus (house-sparrow), 204, 244
Pasteur, Louis, 191
Pea, embryo of, 102 ; seed coat of, 101
Peacock butterfly (*Vanessa Io*), 206, 238
Peltigera, 222
Peptone, 83, 84
Perca fluviatilis (perch), 235
Perch (*Perca fluviatilis*), 235 ; climbing (*Anabas scandens*), 169
Perdix cinereus (partridge), Pl. XV
Perfect flowers, 122, 128
Perianth, 127
Peripatus, 269
Peristalsis, 84
Periwinkle (*Littorina littorea*), 175
Perrier, E., 251
Petals, 112, 113
Phanerogams, 139
Philomachus pugnax (ruff and reeve), 244
Pigeon, 157 *et seq.*
Pike (*Esox lucius*), 235
Pinguicula vulgaris (butterwort), 224
Pistil, 115, 117 *et seq.*
Pistillate flowers, 123, 153
Pitcher-plants, 226
Plant-lice, 203
Plasma of blood, 86, 87
Platypus, 269, 270, 271
Pollen, 105, 115, 118 *et seq.*
Pollination, 119, 141
Potassium, 59
Pro-echidna bruijnii, 270
Protective coloration, 237 *et seq.* ; resemblance, 79, 104
Proteid, 83, 84, 194
Prothalli of ferns, 126, 262
Protoplasm, 27, 28, 32, 35
Privet hawk moth (*Sphinx ligustri*), 20, 231, 256
Pteridium aquilinum (bracken fern), 202, 258 *et seq.*, Pl. V
Ptyalin, 82

Pulmonary sac of snail, 173
Puss moth (*Dicranura vinula*), 239, 240, Pl. XIV

Rabbit, 77 *et seq.*
Radula of snail, 174
Red blood corpuscles, 86, 87
Red underwing moth (*Catocala nupta*), 238
Reindeer 'moss' (*Cladonia rangiferina*), 222
Reptiles, relationship of, to birds, 160
Resemblance, protective, 79
Roman nettle (*Urtica pilulifera*), 155
Roots, plant, 51, 52, 56, 61
Root-stock, 268
Ruff and reeve (*Philomachus pugnax*), 244

Sacculina, 146
Sago-palm (*Cycas revoluta*), 266
Saliva, 82
Salivary glands, 83
Sap, 62
Scales of fish, 167
Sea anemone, 183
Seaweeds, 34
Seeds, dispersal of, 104, 122, 126, 146, 150; fertility of, 104; of pea, 101 *et seq.*; of wallflower, 122; structure of, 104
Self-fertilization, 122, 125 *et seq.*
Semilunar valves, 90
Sepals of flower, 113
Setæ of earthworm, 177
Shepherd's purse (*Capsella bursa-pastoris*), 48
Skeleton, mammalian, 93 *et seq.*; of pigeon, 158; of starfish, 172
Snail, garden (*Helix aspersa*), 172 *et seq.*
Sodium, 59
Sparrow, house- (*Passer domesticus*), 204, 244
Spawn, frog's, 136, 137
Spermatozoa, 105, 134, 136, 160, 181
Sphinx ligustri (privet hawk moth), 20, 231, 256
Spinal cord, mammalian, 96, 97, 98
Spiracles of insect, 179
Spleen, 91
Sporangia, 265, 266
Spores, production of, 260 *et seq.*
Sporoblast of malarial parasite, 218
Sporozoites of malarial parasite, 215 *et seq.*
Stamens, 114, 115, 117 *et seq.*
Staminate flowers, 123, 153
Starch, 31, 65, 86; iodine test for, 65, 66
Starfish (*Asterias rubens*), 170, 171, 172
Stick insect (*Bacteria trophinus*), 240
Stickleback, three-spined (*Gasterosteus aculeatus*), 131 *et seq.*
Stigma of flower, 116, 118
Stinging nettle (*Urtica dioica*), 151 *et seq.*
Stock, ten-week (*Matthiola annua*), 48
Stomach, crustacean, 161; work of, 83
Sucker fish (*Echeneis remora*), 234
Sugar, 72
Sundew (*Drosera rotundifolia*), 225, 226
Sunlight used by plants, 64, 65, 66
Swan (*Cygnus olor*), Pl. XI
Sympathetic coloration, 237 *et seq.*
Sympathetic nervous system, 98

Tadpoles, 197 *et seq.*
Teeth of rabbit, 82
Testa of pea-seed, 101.
Testes, 105, 181
Thistle, white, Pl. X
Toad (*Bufo vulgaris*), Pl. XII
Tongue of snail, 174
Tortoiseshell butterfly, large (*Vanessa polychloros*), 256; small (*Vanessa urticæ*), 238, 256

INDEX

Trachea of insects, 179; of mammals, 85
Transpiration of water by plants, 54
Tree-ferns, 140
Triton cristatus (great crested newt), 244
Trochosphere larvæ, 181, 208
Trophozoite of malarial parasite, 217 *et seq.*
Tropidonotus natrix (grass-snake), 239
Trypsin, 84
Tube-feet of starfish, 171
Tyndall, John, 191

Ulex europæus (gorse), 142, 143, 144
Ulothrix, 200, 201, 202
Underwing moths, 238, 239
Urtica dioica (stinging nettle), 151 *et seq.*
Urtica pilulifera (Roman nettle), 155
Usnea, 222
Utricularia vulgaris (common bladderwort), 227

Vacuoles, 32; contractile, 41
Vallisneria spiralis (eel-grass), 127, 128
Valves of the heart, 90; of the veins, 92
Vanessa Io (peacock butterfly), 206, 238
Vanessa polychloros (large tortoiseshell butterfly), 256
Vanessa urticæ (small tortoiseshell butterfly), 238, 256
Vascular bundles, 53
Veins, 89, 91
Ventricles of the heart, 88
Venus' fly-trap (*Dionæa muscipula*), 226
Vertebræ of mammal, 97
Viscum album (mistletoe), 145, 146
Vitelline membrane, 105
Voluntary muscle, 96
Volvox globator, 38

Wallace, Alfred Russel, 248 *et seq.*
Wallflower (*Cheiranthus cheiri*), 47 *et seq.*
Warmth, response of animals to, 26
Warning colours, 237
Water, 72; composition of, 70
Water-lily, white (*Nymphæa alba*), 147 *et seq.*, Pl. VIII, Pl. IX
Water-vascular system of starfish, 171
Water vessels of plants, 53
Weismann, August, 254
White dead-nettle (*Lamium album*), 152
White matter of brain, 97
Wilberforce, Samuel, Bishop of Oxford, 246
Willow, flowers of, 124, 125, Pl. VI, Pl. VII
Wind-fertilization, 118, 124, 125, 153

Yellow-hammer (*Emberiza citrinella*), nest and eggs of, Pl. II

Zooids, 202
Zoophytes, 183
Zygotes of malarial parasite, 218

Third Impression

THE EARTH AND ITS LIFE

BY

A. WADDINGHAM SEERS B.A.

Author of *The Story of Early English Travel and Discovery*

Crown 8vo, 208 pages, 80 illustrations, cloth boards, 2s.

EXTRACTS FROM PRESS NOTICES

" The formation of the earth and the development and spread of life are here described in a story which boys and girls from twelve or thirteen onwards and many grown-up people will find as engrossing as any fairy tale."—*Times Educational Supplement.*

" This little book describes the evolution of life upon the earth from the earliest days to the dawn of our present civilization. The story is told simply and vividly, and the result is a romance which should appeal strongly to old and young readers alike. The book is copiously illustrated, and should find a welcome as a school reader. It makes its appeal at the same time to the romantic and scientific spirit, and its value is beyond question." —*Education.*

" A fascinating account of the history of the earth, told in simple language for children. Miss Seers presents the conclusions of the geologists, the palaeontologists, the botanists, and the ethnologists in a clear, vivid, and instructive manner. The book would be an admirable supplementary reader for senior pupils, who could not fail to derive from it a keen sense of the mystery and wonder of the world."—*Scottish Educational Journal.*

" Miss Seers writes in an interesting manner of the evolution of life on the earth culminating in the appearance of man. Her book is full of interest and her narrative charming in style and simple to read. . . . We do most heartily commend this book to the attention of our readers."—*Secondary Education.*

" An admirable little book, well planned and simply written, tracing the story of the earth from its origin to the dawn of history. . . . The illustrations are good and appropriate."—*Child Life.*

ANCIENT MAN

BY

HENDRIK WILLEM VAN LOON

Author of *The Story of Mankind*

Size 7×4¾ inches. 224 pages. 3s. 6d. net.

Illustrated by the Author

EXTRACTS FROM PRESS NOTICES

"Mr Van Loon's book has sterling merits, not the least of which are his candour and his freshness of outlook."—*Aberdeen Press and Journal.*

"It is a book written for children, explaining in child-like language the history of mankind from the beginnings, so far as we can penetrate by the aid of imagination and geological remains. We say 'child-like' language, which is at the very opposite pole from 'childish.' . . . Indeed, no better description can be applied to the manner of the telling of the story than that which has already been used in his *Story of Mankind. Ancient Man* also belongs to that noble department of literature in which the 'words are for children and the meanings are for men.' . . . He tells his tale with joy, and with humour too."—*Cassell's Weekly.*

"Mr Van Loon's book is written in a simple style that is excellent reading for children and adults. . . . It is the result of a genuine attempt at the extraordinarily difficult task of giving in a few main outlines the history of Ancient Man briefly, intelligibly, and in correct proportion. . . . Mr Van Loon is carefully correct in his facts."—*Daily Herald.*

"Mr Hendrik W. Van Loon, whose *Story of Mankind* achieved a great success, has now written *Ancient Man*, a narrative of the beginnings of civilization. The first chapter is on prehistoric man, and the seventeenth chapter on the end of the ancient world. Between these we have accounts of the earliest school of the human race, the making of a state, Egypt, Assyria, and Babylonia, the story of Moses, and so forth. . . . The narrative is marked by simplicity, comprehensiveness, and vital interest."—*The Northern Echo.*

"The method is sound and the book itself a remarkable achievement. . . . Told in simple, but, wisely, not too simple, language, and really brilliantly illustrated by the author's sketches, the story is never allowed to deviate from its subject, which is not Egypt nor any other land, but man; and the account of how civilization after civilization formed him is as fascinating as a fairy tale."—*Scottish Nation.*